Progress report (Q4 FY13 / Q1 FY14)
Fast and lightweight tracking systems
Barrel MicroMegas
&
Forward Triple-GEM

Maxence Vandenbroucke
Bernd Surrow (PI)

Doug Hasell

Franck Sabatie (PI)

Project overview

- Progress report: Q4 FY13 / Q1 FY14
  - R&D effort focuses on intermediate tracking system:
    - Barrel tracking system based on MicroMegas detectors manufactured as cylindrical shell elements and
    - Forward tracking system based on triple-GEM detectors manufactured as plan segments.
  - R&D effort - Main strategy:
    - Design and assembly of large cylindrical MicroMegas detector elements and planar triple-GEM detectors
    - Test and characterization of MicroMegas and triple-GEM prototype detectors
    - Design and test of new chip readout system employing CLAS12 'DREAM' chip development
    - Utilization of light-weight materials
    - Development and commercial fabrication of various critical detector elements
    - European/US collaborative effort on EIC detector development (CEA Saclay, MIT and Temple University)

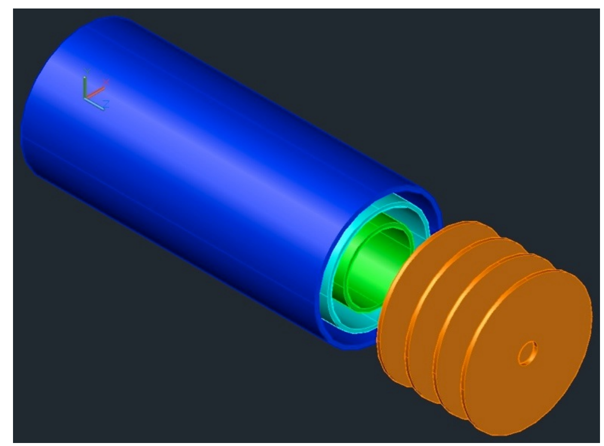
Design and assembly of fast and light-weight barrel and forward tracking prototype systems for an EIC

Progress report (Q4 FY13 / Q1 FY14)

S. Aune, E. Delagnes, M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié[1]
CEA Saclay

P. Bull, A. Dumont, C. Harris, R. Harris, D. S. Gunarathne, E. Kaczanowics, A. F. Kraishan, X. Li, M. McCormick, G. Miller, D. L. Olvitt, B. Surrow[2], M. Vandenbroucke and G. Zangakis
Temple University, College of Science and Technology

J. Bessuille, B. Buck, D. Hasell
MIT, Laboratory for Nuclear Science



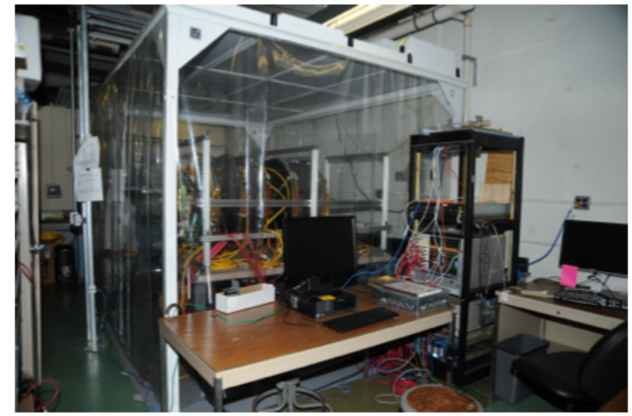
Progress report - Q4 FY13 / Q1 FY14

Forward GEM tracking - Laboratory setup

- Setup of two labs, a detector lab and dedicated clean room in the current Department of Physics at Temple University (New Science Education and Research Center ready by summer 2014) in addition to existing resources at MIT Bates
- Engineering resources at TU with Ed Kaczanowics (Mechanical engineer) and at MIT Bates with Ben Buck (Electrical engineer) and Jason Bessuille (Mechanical engineer)
- Design of dedicated large-size N2 storage shelves for GEMS
- Design and preparation of large assembly tools will start in spring 2014 by a new mechanical engineer

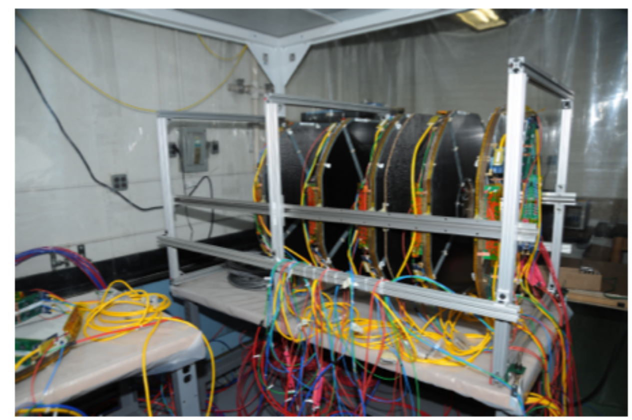
Detector lab at Temple University
(Current Department of Physics)

(a)



(b)

(c)



(d)

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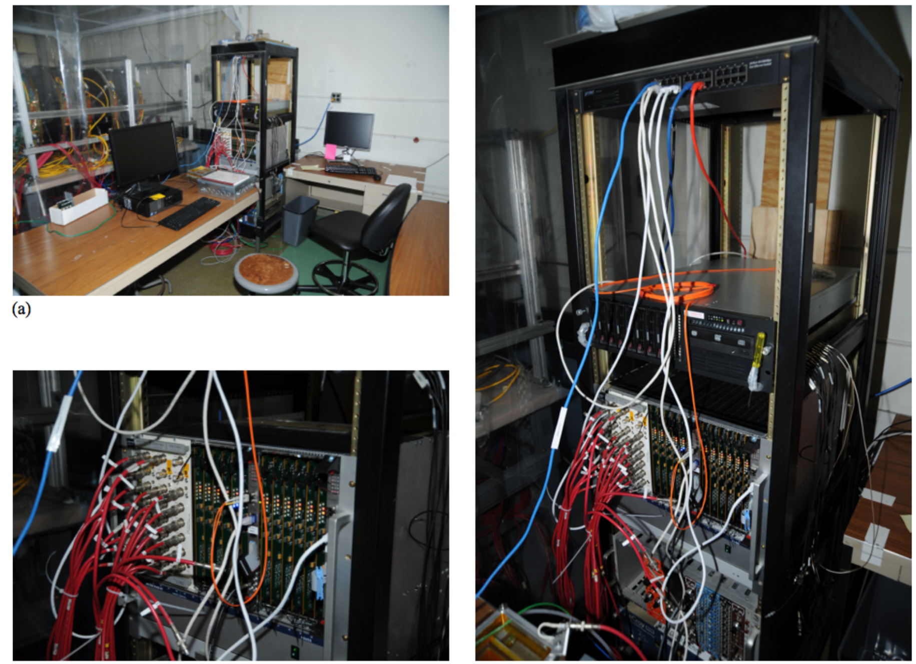
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - DAQ system

  - Setup of DAQ system profits enormously from synergy with STAR FGT DAQ system
    - In place: Special Wiener crate (3 HV modules, 2 control modules and 2 X 6 readout modules (ARC))
    - Completed DAQ system:
      - DAQ computer
      - Run control / Slow control computer
      - HV modules (3)
      - Readout modules (2 X 6)
      - Control modules (2) and
    - Run control and slow control operational / Copy of STAR DAQ setup

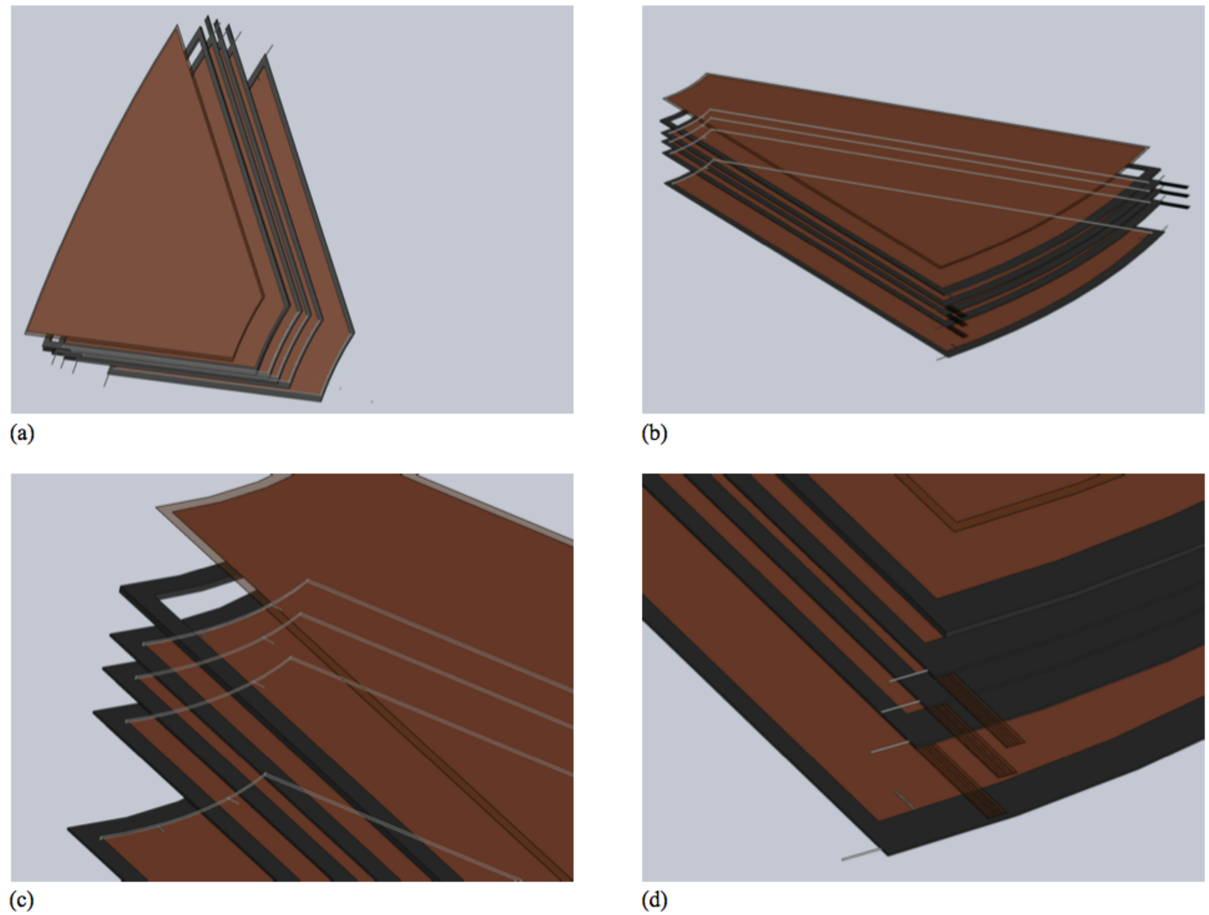


(a) (b) (c)

Progress report - Q4 FY13 / Q1 FY14

Forward GEM tracking - Design of large triple-GEM segment

- Commercial fabrication of single-mask process started
- GEM frames based on Carbon material for self-support
- No spacers (Kapton ring)
- Gas piping in each CC frame
- HV routing realized through Kapton PCB extended by flaps for connection to HV distribution
- Design review by MIT Bates engineering team followed by procurement of large foils, initially at CERN


(a) (b) (c) (d)

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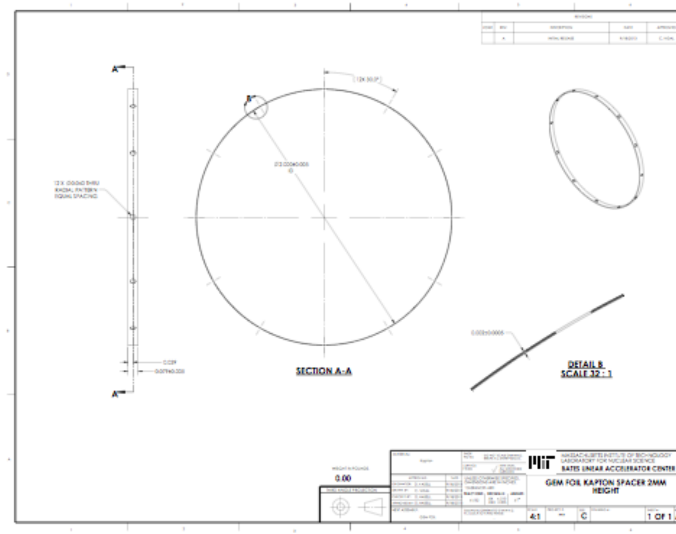
Doug Hasell and Franck Sabatie (PI)

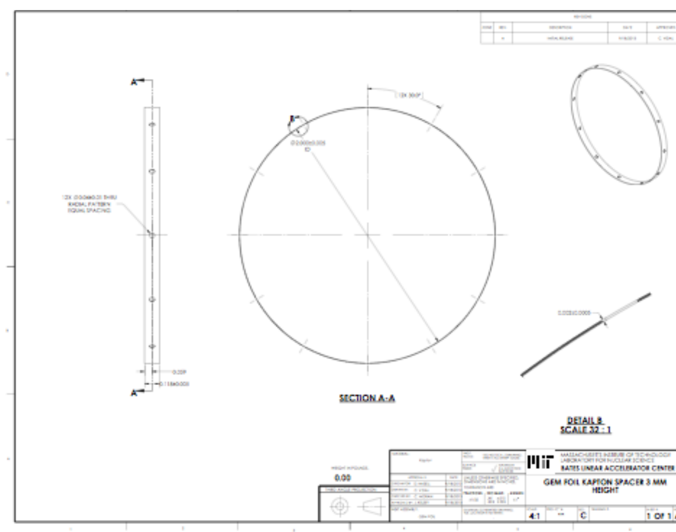
Progress report - Q4 FY13 / Q1 FY14

Forward GEM tracking - Kapton ring details

- Kapton ring design finalized.
- Commerical source for fabrication identified (POTOMAC, Lanham, MD)
- 2 or 3 mm in height:
  - 2 mm for GEM gap
  - 3 mm for HV (and PV) gap
  - Tolerance on height ±0.3 mm
- Expect to start with assembly of Kapton-ring based triple-GEM detector in spring 2014 after delivery of Kapton rings



(a)



(b)

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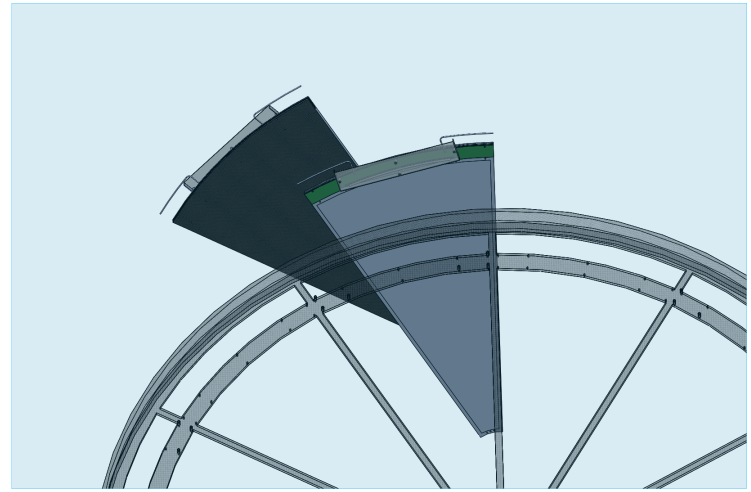
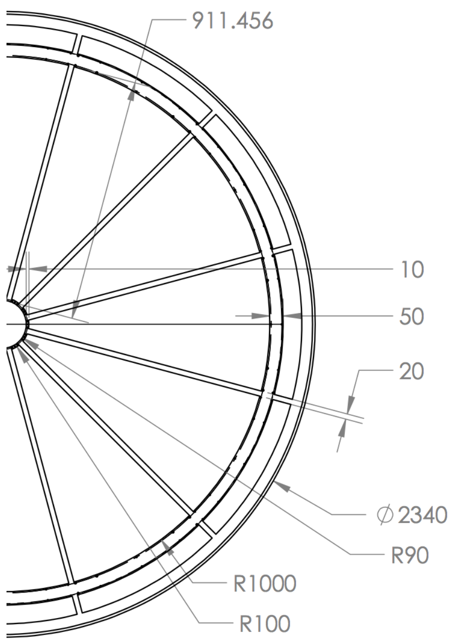
Doug Hasell and Franck Sabatie (PI)

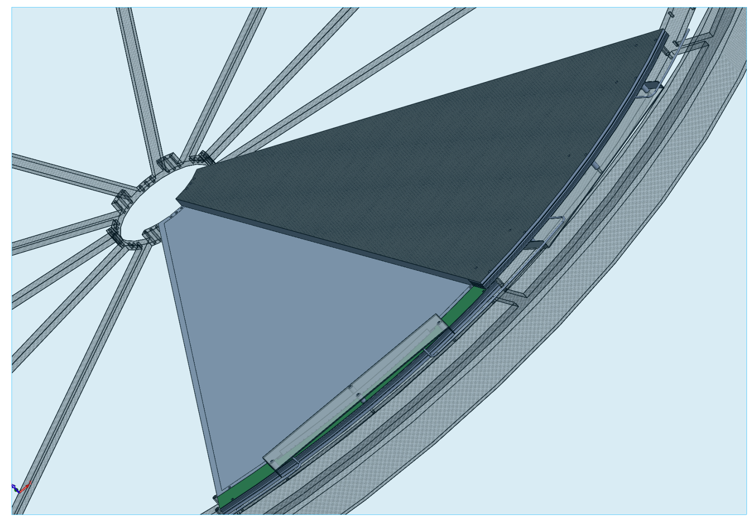
Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - Mechanical design
  - Light weight design allows minimal support structure
  - Initial discussion with E. Anderson (CC shop, LBL) very encouraging / Plan to prototype part of support structure after MIT Bates design review





Wheel dimensions (cm)



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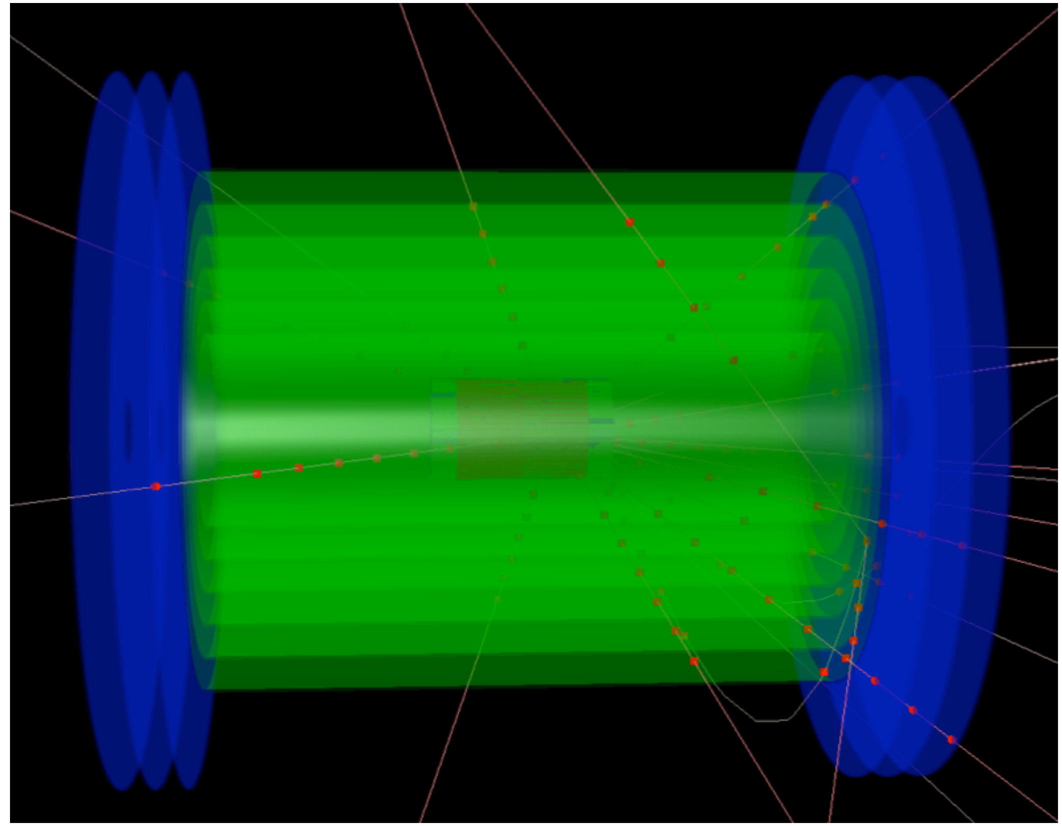
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

- EICROOT Simulations
  - EICROOT package + Smearing
  - Focus on Tracking and the Energy resolution
  - Geometry implementation started
  - Forward GEM: 3 FGT-type disks with r_{in} = 10cm and r_{out} = 100cm
  - Barrel MicroMegas: 6 cylindrical barrel layers
  - Simulations include the Barrel Silicon Tracker and Forward Silicon Tracker



Objectives

=> Good definition of the general FGT geometry

=> Comparison of the Micromegas barrel with a TPC

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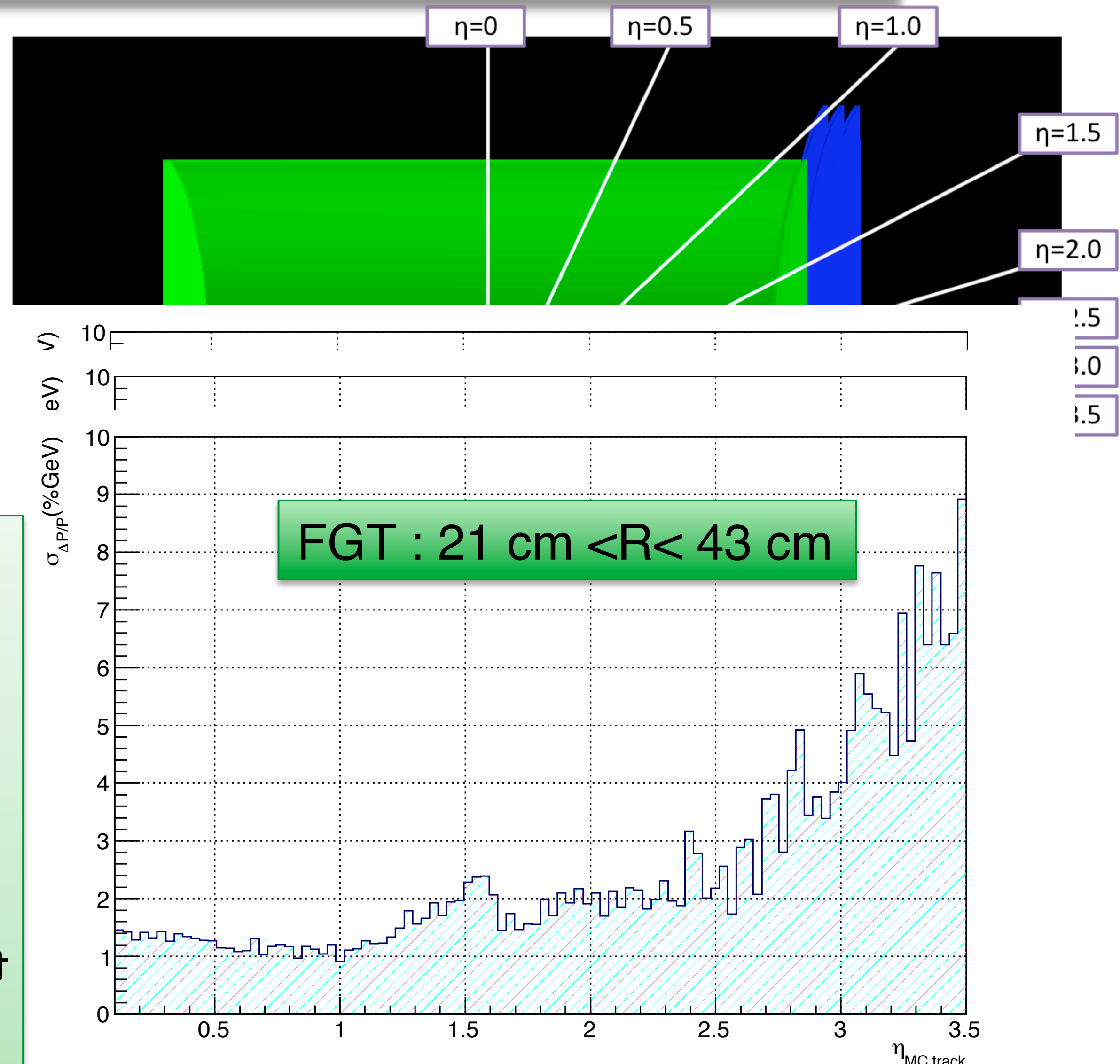
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

- Simulations – FGT Size Studies
  - Studies aiming to constrain the size of a forward GEM system (Studies based on TPC barrel system)
  - Box generator : π^-@10GeV/c, 10k events



- FGT acceptance should match the central tracker
- No material in the acceptance of the silicon tracker disks (BST/FST)
- Impact of material budget not clear, depends on the physics

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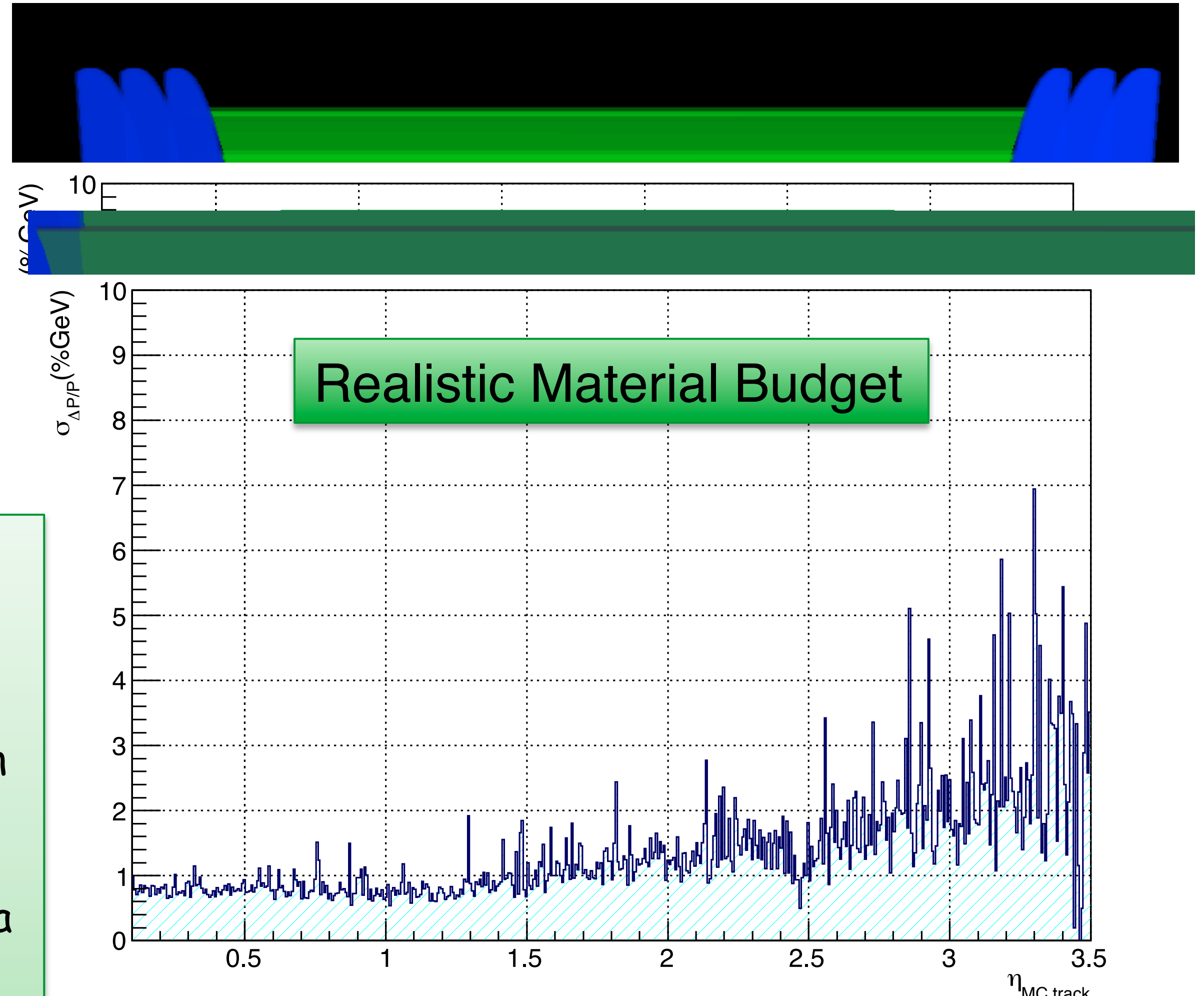
Progress report - Q4 FY13 / Q1 FY14

- Simulations – Micromegas Barrel
  - Same software environment
  - 6 barrels from 20cm to 80cm radii
  - 2 chambers per barrels for 2 dimension readout
  - 200μm spatial resolution (using smearing package)



- Micromegas Barrel is a realistic solution
- Realistic material description
- Initial studies point to an improved p_T resolution with a MicroMegas barrel system

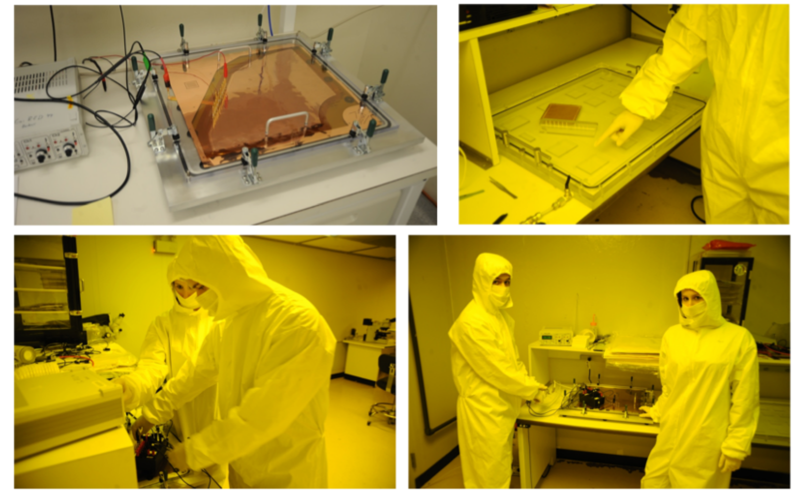
Maxence Vandenbroucke, Bernd Surrow (PI),
Doug Hasell and Franck Sabatie (PI)

Project overview

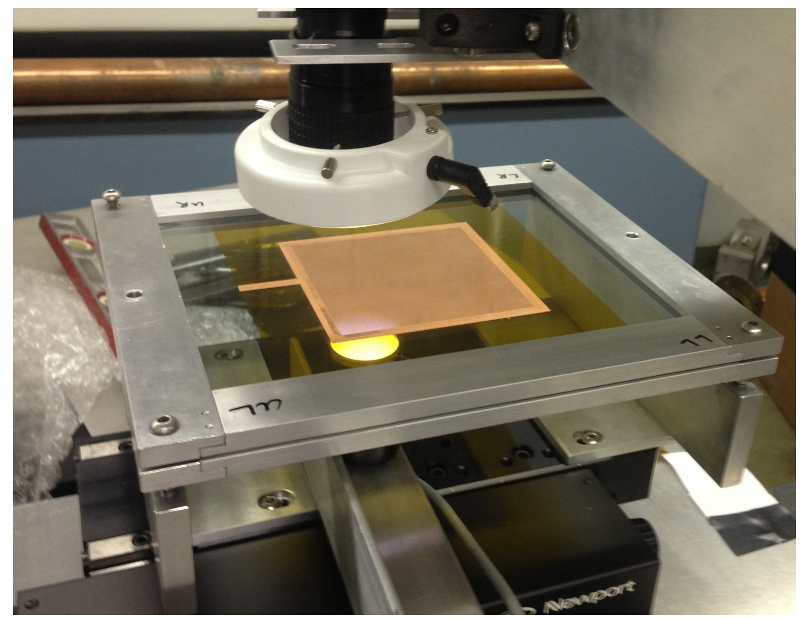
Executive Summary of Forward triple-GEM

- Setup of two labs, a detector lab and dedicated clean room in the current Department of Physics at Temple University completed (New Science Education and Research Center ready by summer 2014) in addition to existing resources at MIT Bates
- Characterization of GEM foils in terms of leakage current and optical uniformity routinely performed
- Assembly of small (10 X 10 cm^2) triple-GEM test detectors
- Setup of cosmic-ray test and 55Fe source scanner
- Setup of DAQ and HV system completed
- Mechanical design studies on large triple-GEM detector segment and initial discussion with LBL CC shop
- Commercialization of large GEM foil production using single-mask manufacturing techniques started
- Simulations within the EICROOT framework of the FGT

Leakage current measurement



CCD scans



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FROM RESEARCH TO INDUSTRY

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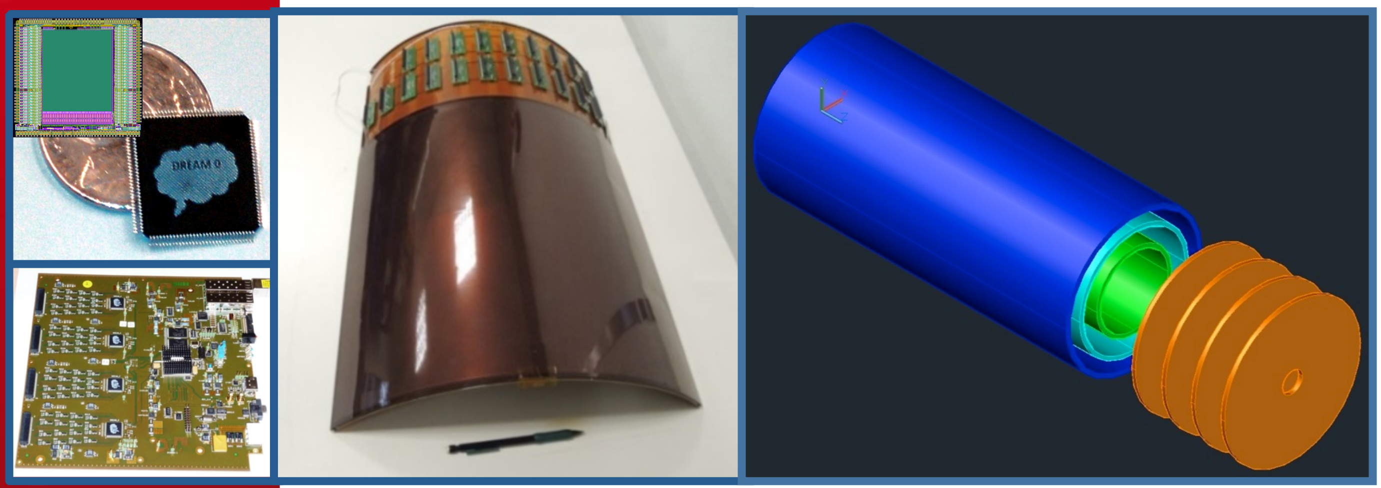
Micromegas
EIC R&D project



F. Sabatié – Irfu/SPhN

Jan. 13th 2014

www.cea.fr

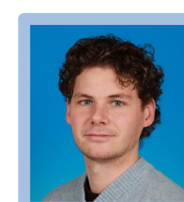
EIC Generic Detector R&D Meeting
Upton, NY, January 13, 2014

Maxence Vandenbroucke, Bernd Surrow (PI),
Doug Hasell and Franck Sabatié (PI)

Micromegas R&D - the actors at Saclay

A. Acker, D. Attie, S. Aune, J. Ball, M. Boyer,
G. Charles, E. Delagnes, M. Garçon, A. Giganon,
J. Giraud, R. Granelli, N. Grouas,
I. Mandjavidze, C. Lahonde, O. Meunier,
Y. Moudden, S. Procureur, F. Sabatié (PI)

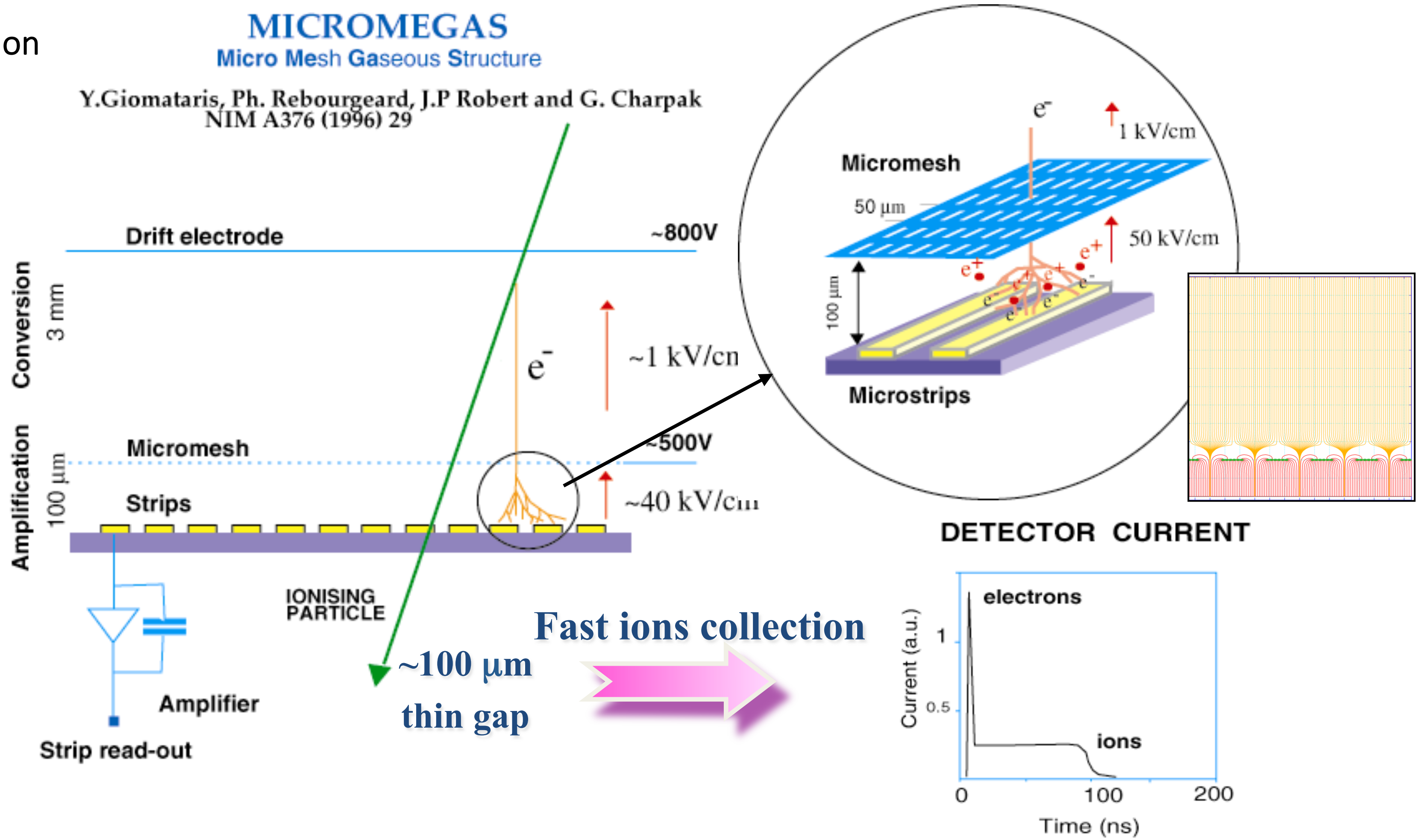
+ M. Vandenbroucke (since 11/2013)



A brief history of Micromegas technology

1996

invention

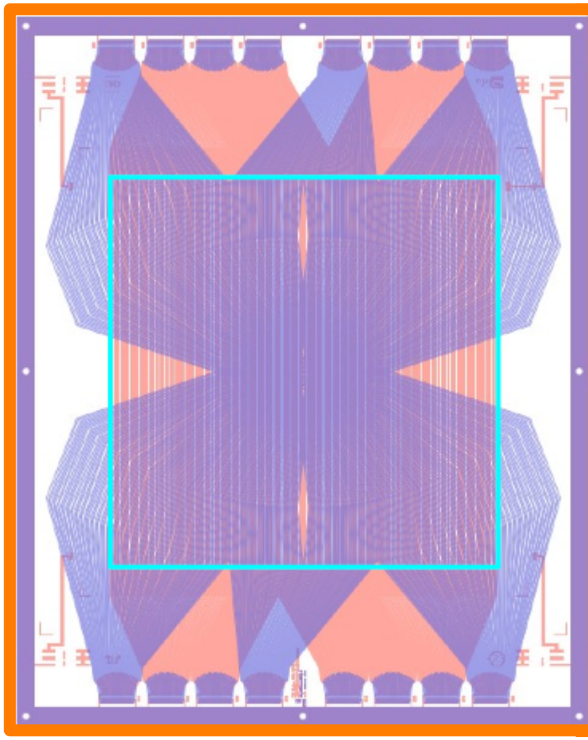


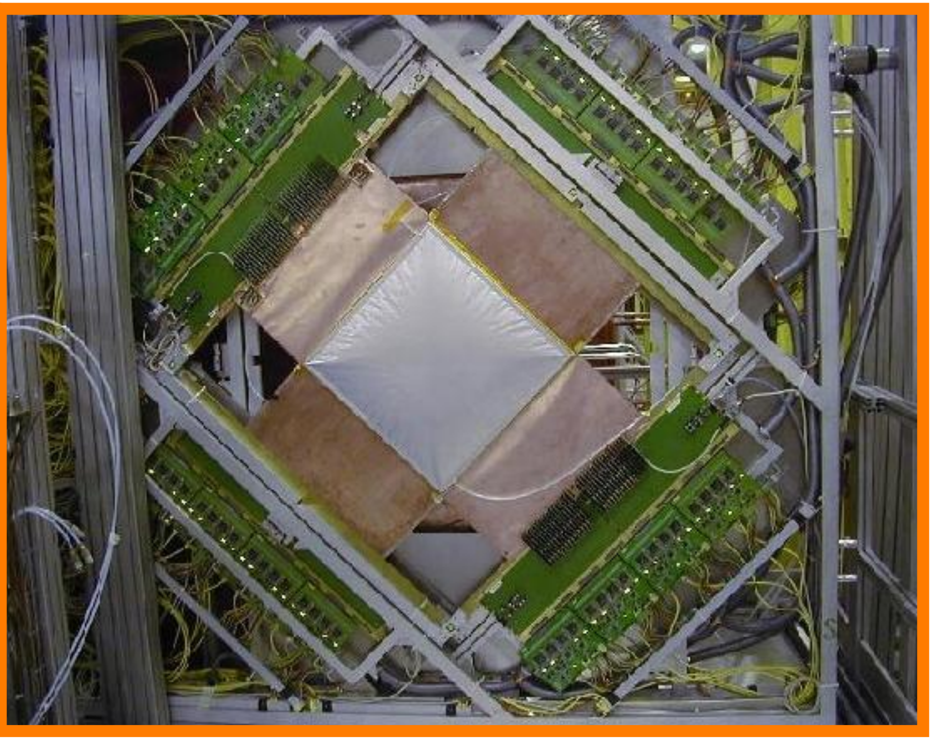
A brief history of Micromegas technology

1996 — invention

2002 — 1st use in expt

- *COMPASS @ CERN*
- *A decade of smooth operation*
- *No ageing seen*





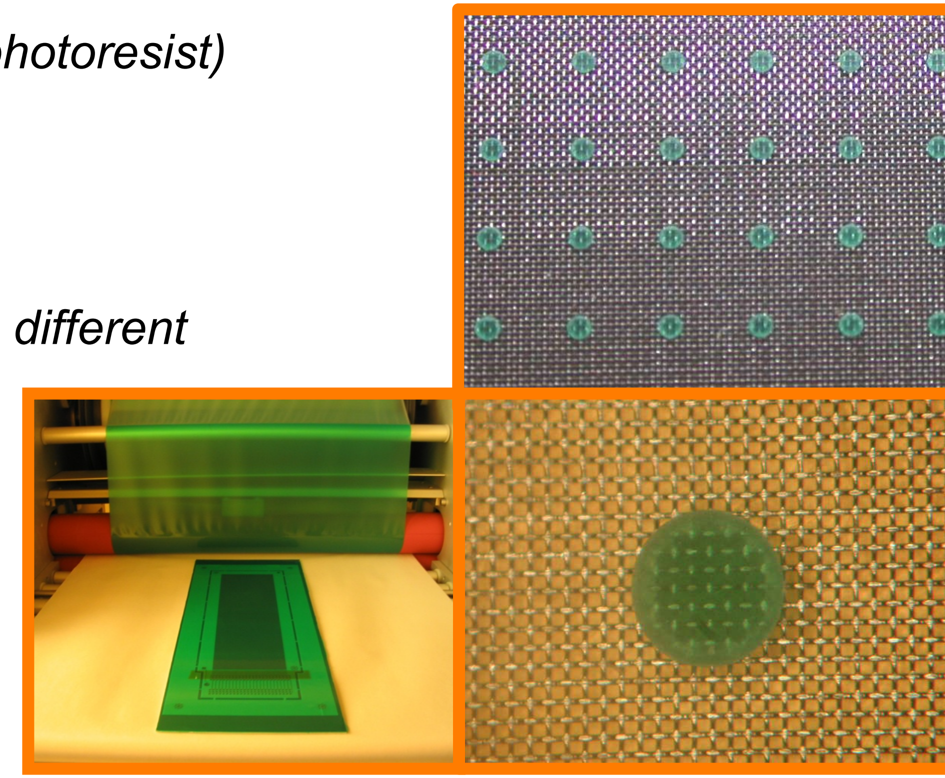
A brief history of Micromegas technology

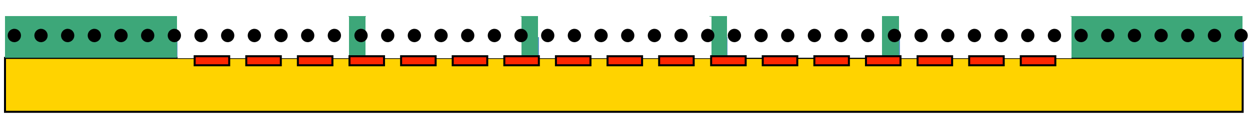
1996 → invention

2002 → 1st use in expt

2006 → bulk process

- *More robust (mesh is embedded in photoresist)*
- *Simplified mechanical structure*
- *Ability to use thin PCBs and produce different shapes (cylindrical detectors !)*
- *Ability to industrialize the process*
- ***Cheap !!!***





A brief history of Micromegas technology

1996 — invention

2002 — 1st use in expt

2006 — bulk process

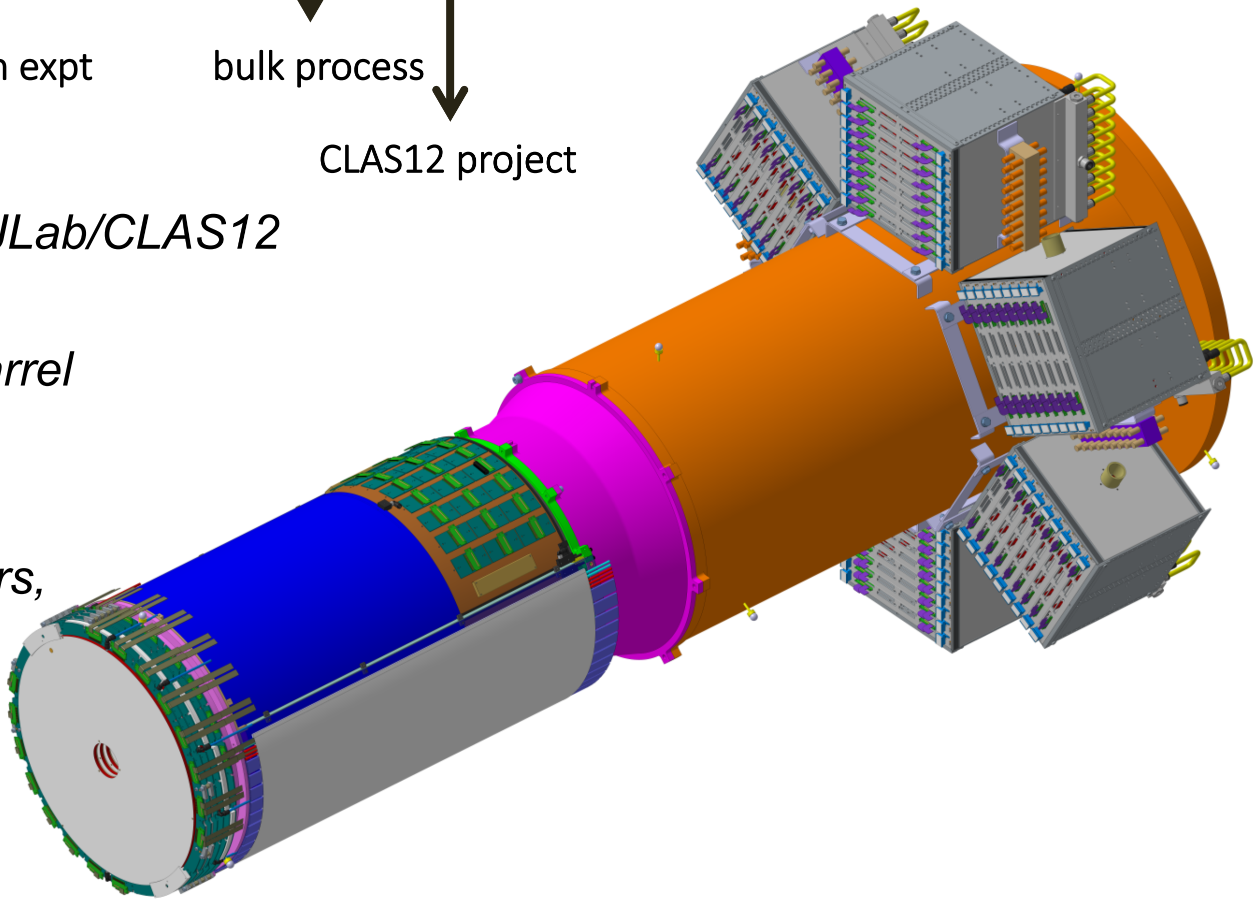
2007 — CLAS12 project

- *Micromegas tracker for JLab/CLAS12*

- *Forward + Cylindrical Barrel*

- *Triggered a lot of R&D*

(new ASIC, flexible detectors, long flex cables, etc)



A brief history of Micromegas technology

1996 — invention

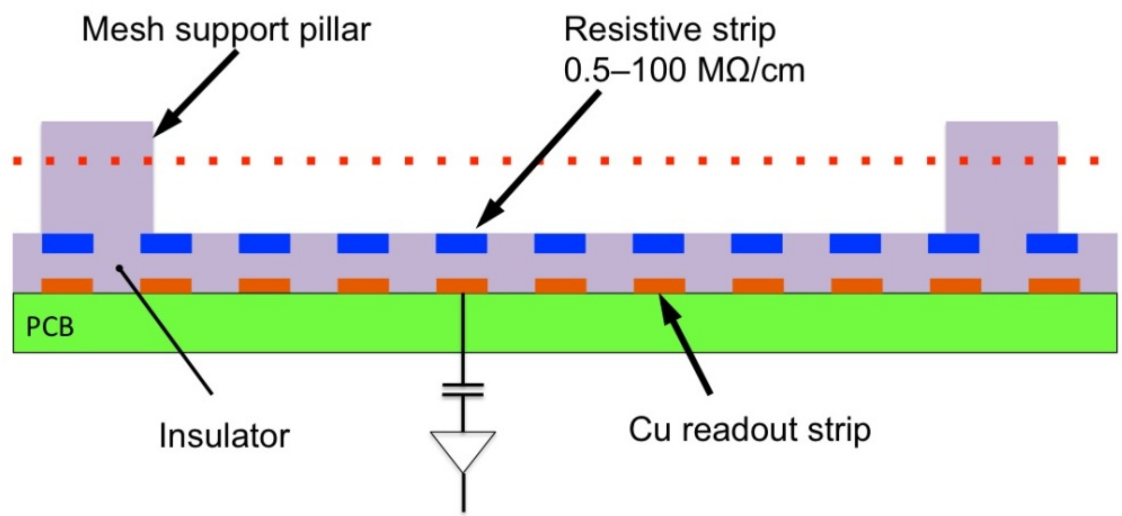
2002 — 1st use in expt

2006 — bulk process

2007 — CLAS12 project

2010 — resistive technology

- *Capacitive readout*
- *Quenches sparks (max 1V HV drop)*
- *No ageing seen*
- *Higher flux capability*



A brief history of Micromegas technology

1996 — invention

2002 — 1st use in expt

2006 — bulk process

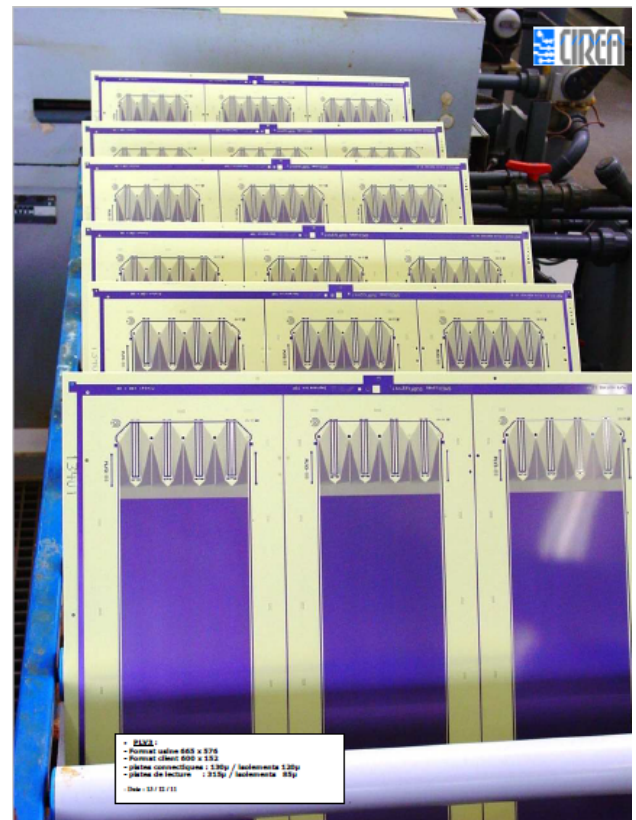
2007 — CLAS12 project

2010 — resistive technology

2012 — 1st MM from ELVIA/CIREA

- *Industrialization => large production capabilities*

- *1st industry prototype successfully tested for CLAS12*



A brief history of Micromegas technology

1996 – invention

2002 – 1st use in expt

2006 – bulk process

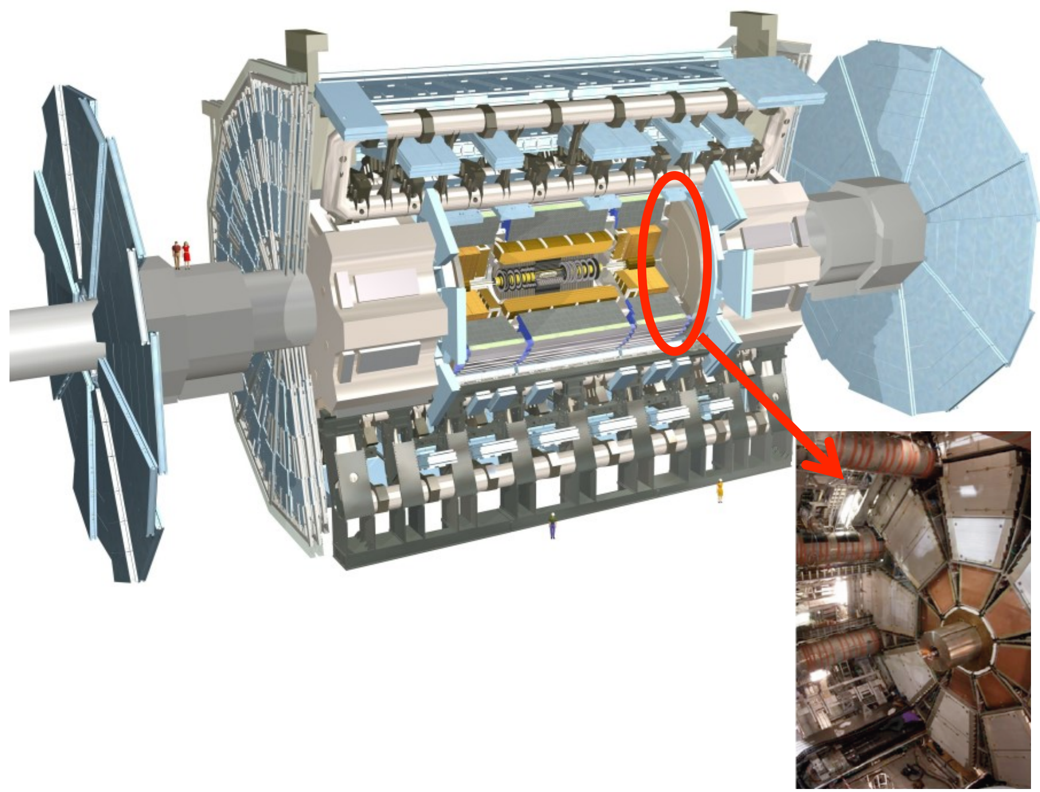
2007 – CLAS12 project

2010 – resistive technology

2012 – 1st MM from ELVIA/CIREA

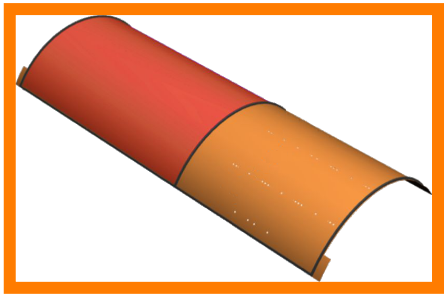
2013 – MM chosen for sLHC/ATLAS

- *ATLAS small wheel*
- ***1200 m²** of Micromegas detectors to build !*
- *Industrialization process intensified*

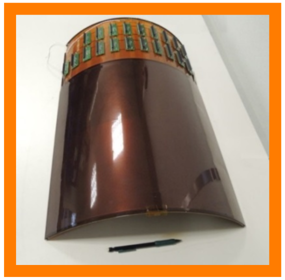


EIC R&D : Micromegas for a lightweight barrel detector

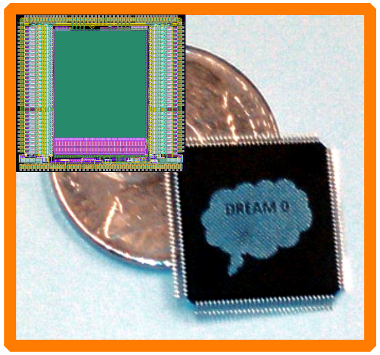
Large detectors manufacturing process



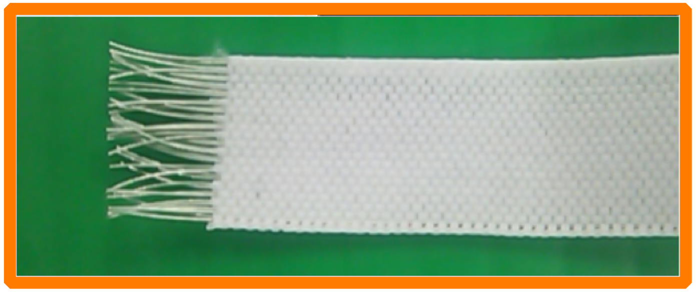
Lightweight mechanical structure



Next-gen dedicated ASIC tailored for large capacitance detectors

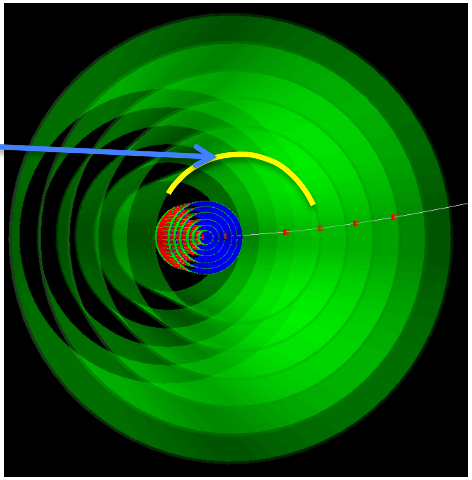


Low-capacitance micro-coax cables

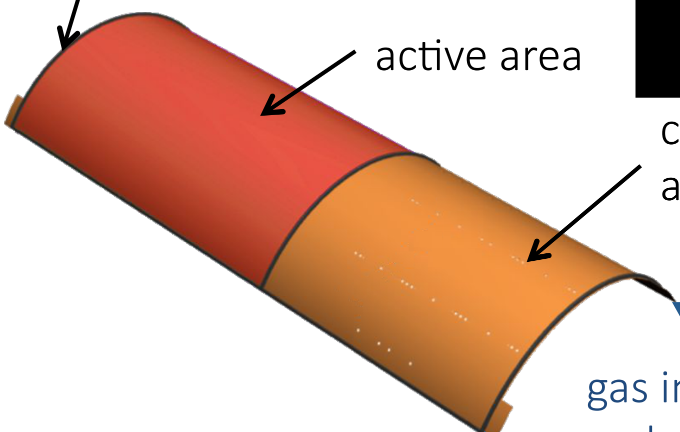


Lightweight mechanical structure, cylindrical detectors

120° tile



Self-sustaining carbon structure



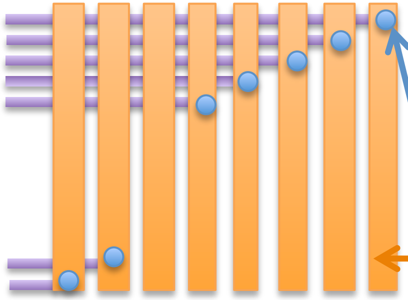
active area

connectors area

gas in/out through carbon structure

1st fully fonctional prototype

Return strips for « C » detectors

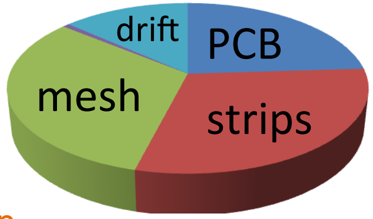


beam direction

via for return strip

signal strip

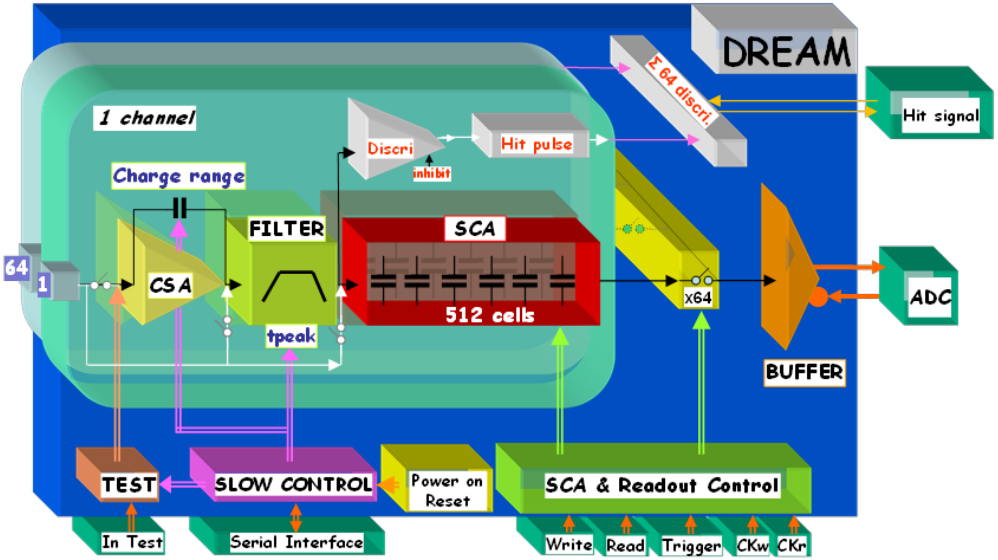
material budget

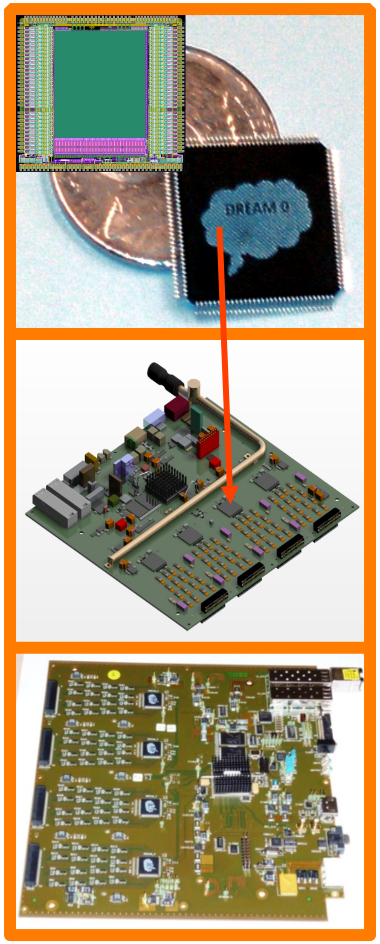


Specifications :

- active area : 40x45cm² r=225mm
- 575 µm pitch
- resistive strips
- kapton drift
- 200µm PCB, total 0.25% X_0/layer

Next-gen ASIC : DREAM





First front-end prototype

- Evolution of AFTER and APV25 chips
- Tailored for high capacitance detectors (MPGDs)
- Dead-time free
- Low noise : 2100e-

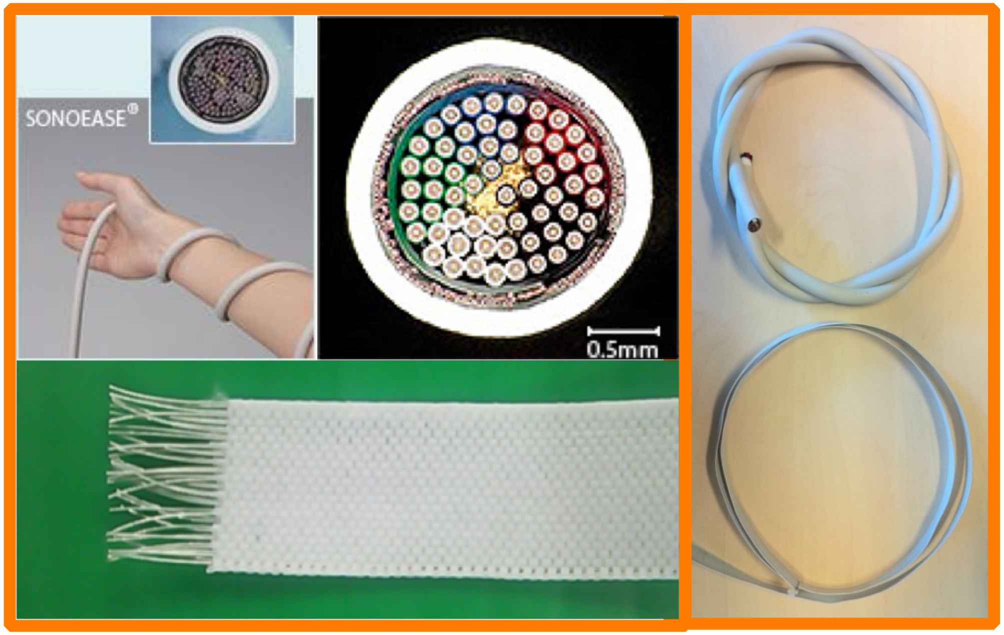
- v0 chip validated in 2012
- Sample of v1 chip received summer 2013
- Full production of final revision in March 2014

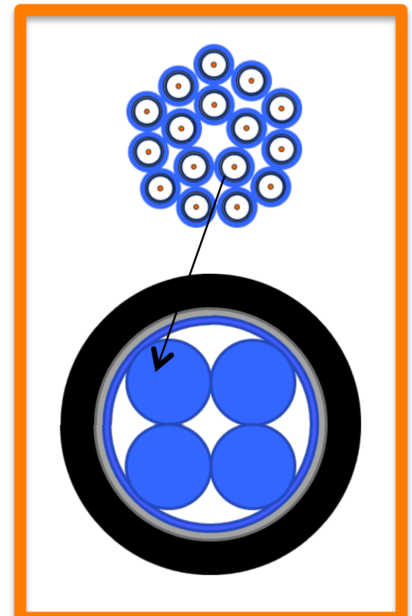
- Gain in S/N up to 25% wrt previous chip generation
- Self-triggering capabilities (part of EIC R&D, successfully tested !)

- Front-end unit prototype received, tested, validated. 12 boards ordered (6000 channels)
- Production of 70 units for 2014 (part of which is for this proposal)

Low capacitance micro-coax signal cables

- R&D started for CLAS12
- <u>Goal :</u> reduce capacitance of signal cables, keep good S/N
- First cables had a capacitance of 240 pF/m, triggered further R&D
- Now micro-coaxial cables made by Hitachi have a capacitance of about 45 pF/m

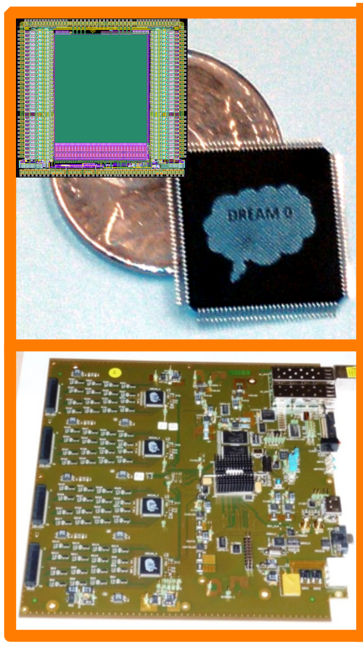


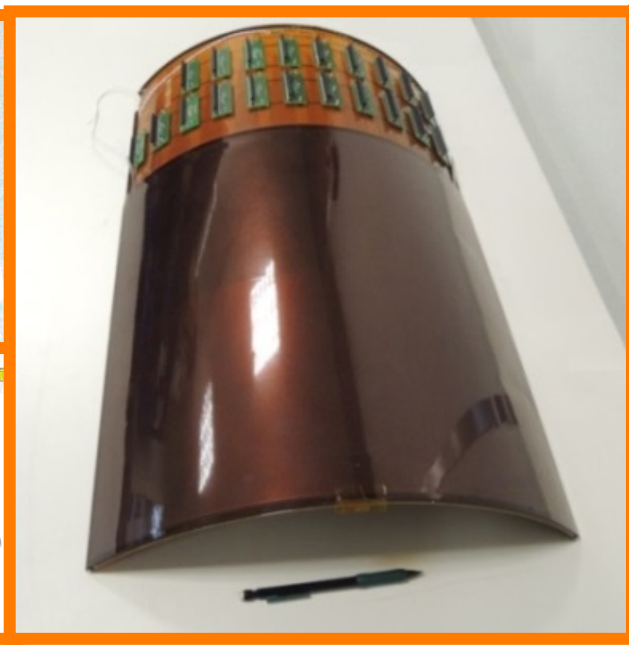


- 100 units of 2m-long cables expected in January 2014

Micromegas R&D next year

- M. Vandenbroucke arrived at Saclay in November 2013
- Early 2014 : design and fabrication of 2 “EIC” prototypes
- Spring 2014 : Characterization and tests with the Dream ASIC
- Simulation/tracking work in 2014





Summary

- Forward GEM tracker
  - Characterization of GEM foils in terms of leakage current and optical uniformity
  - Assembly of small (10 X 10 cm^2) triple-GEM test detectors
  - Setup of cosmic-ray test and 55Fe source scanner / DAQ and HV system
  - Mechanical design studies on large triple-GEM detector segment and support structure
  - Commercialization of large GEM foil production using single-mask manufacturing techniques
  - Spacer grid studies: Grid and Kapton rings
  - Simulation within EICROOT ongoing
- Barrel Micromegas tracker
  - Design of two 120° Micromegas tiles ongoing
  - Last revision of Dream ASIC submitted for production
  - First version of Front-End Electronics card tested and validated
  - Prototypes of light-weight, low capacitance flex cables tested and validated
- Successful undergraduate student recruitment with strong support from TU College of Science and Technology

- Outlook for 2014
  - Expect to order large GEM foils in FY14
  - Order of two 120° Micromegas tiles, test, characterization with final Dream chip + Front-End
  - More simulation work

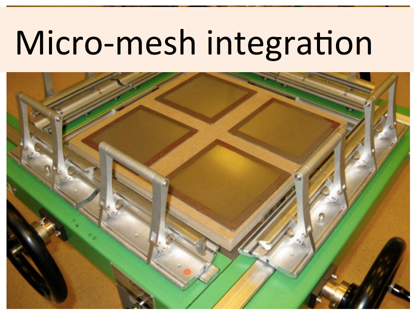
Backup slides

Bulk Micromegas : Fabrication scheme

- First prototypes in 2004. Collaboration CERN/Irfu.
- The woven micro-mesh is laminated between two photo-sensitive layers → reduction of dead zones
- Large areas
- Robust, industrial process (printed circuit)

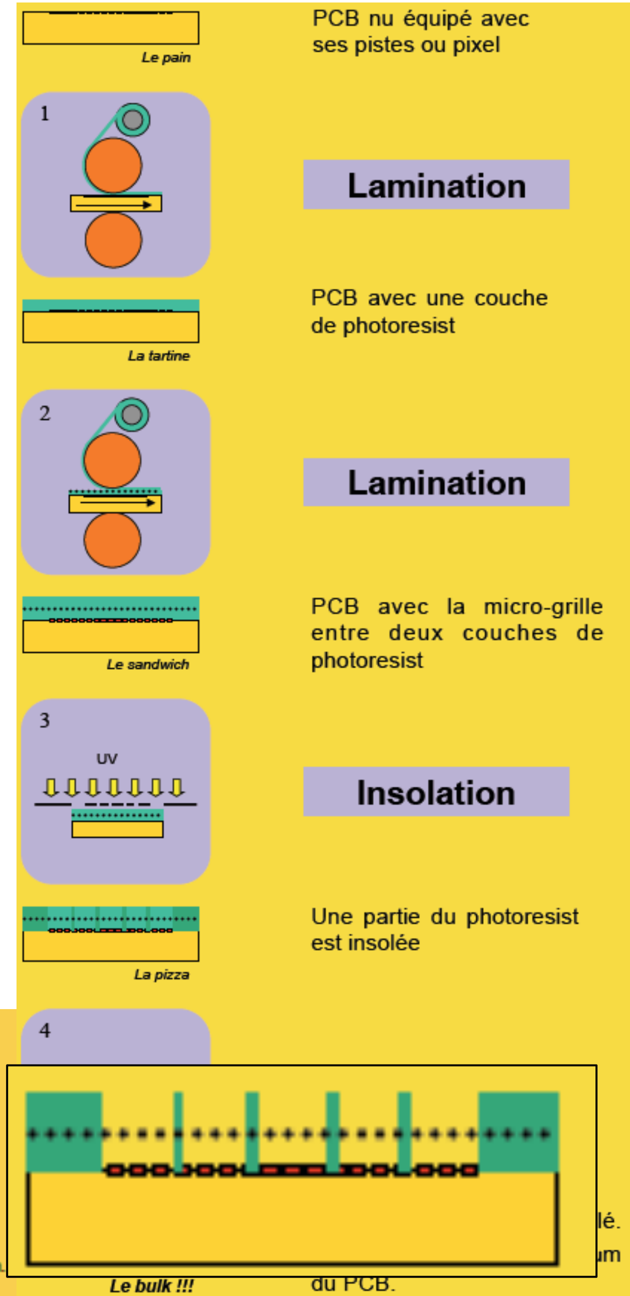
BULK workshop at Irfu/Sedi

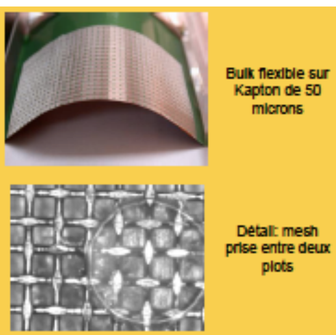

Lamination


Micro-mesh integration

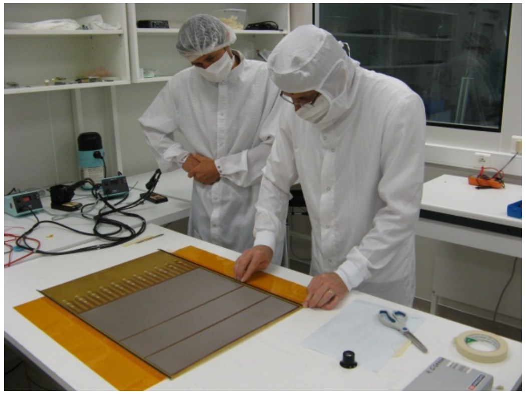

Insolation


Development

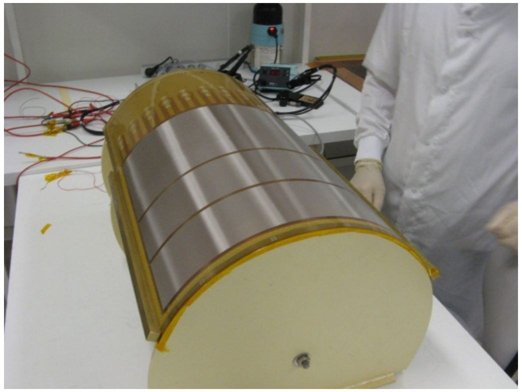




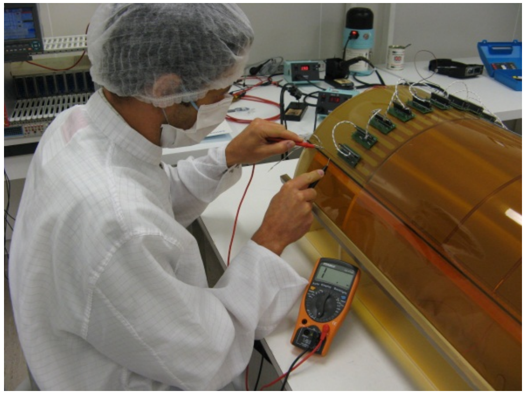
Curved Micromegas : Fabrication process



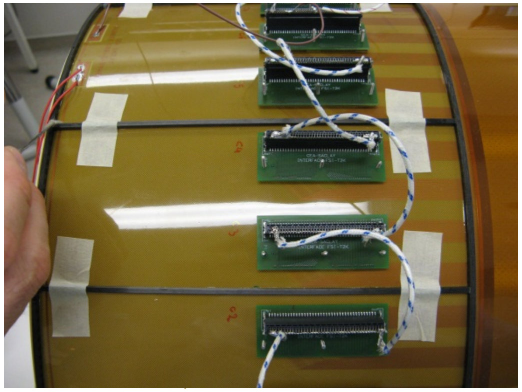
Segmentation and preparation



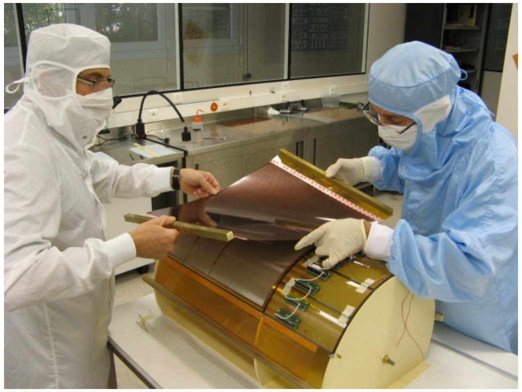
Gluing of the side carbon ribs on circular shape

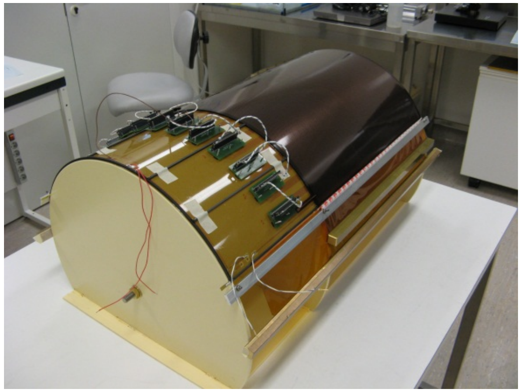


Electric leak test



Gluing of additional ribs





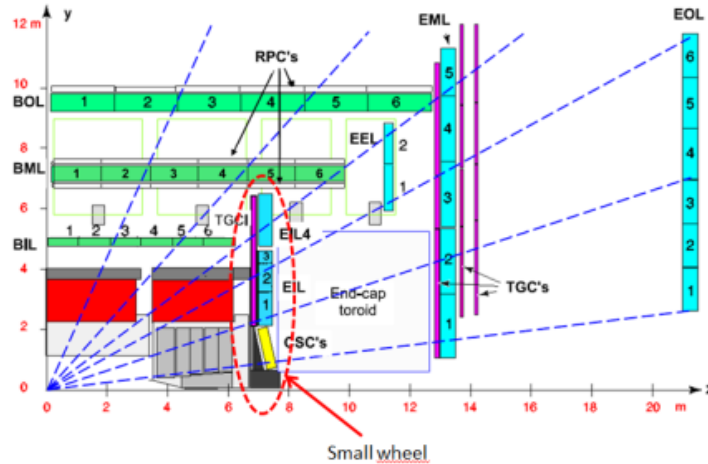
Setting and gluing of drift plane

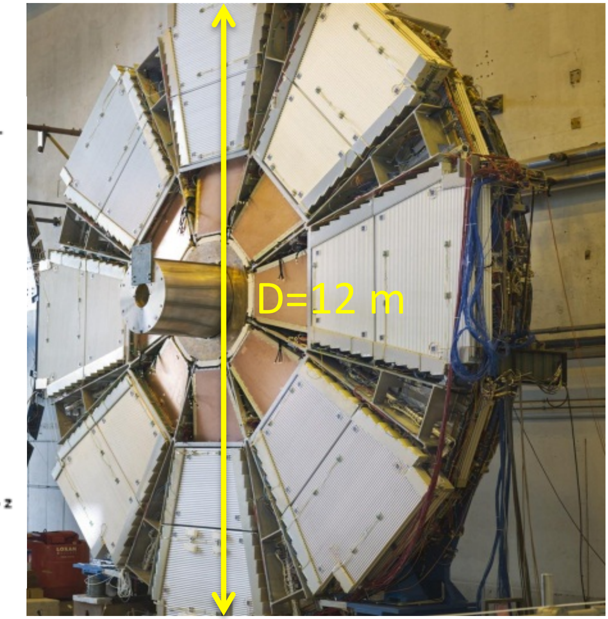
ATLAS Micromegas small wheel project

ATLAS/NSW

2 new wheels (NSW):

- 1200 m^2 of resistive Micromegas
- More than 2M electronics channels



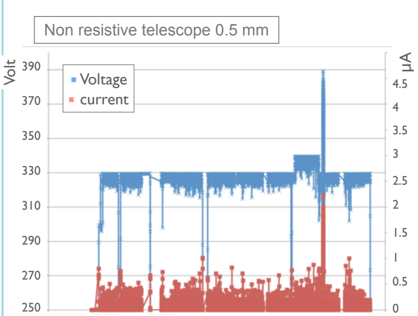


High flux et sparking

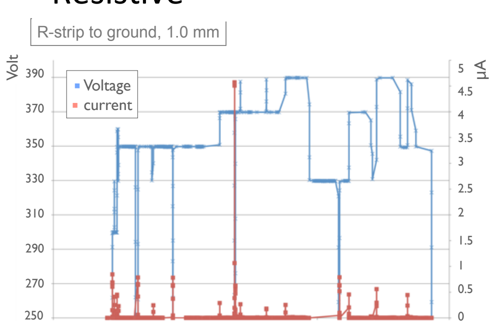
Resistive anodes:

- Reduced spark amplitude
- No dead time
- Robustness

Non resistive



Resistive

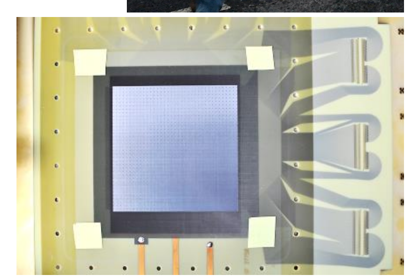


Fabrication

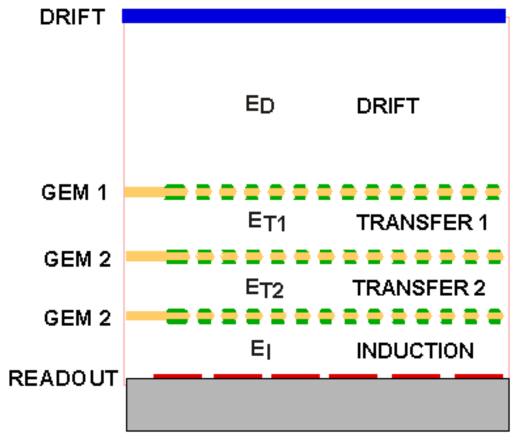
- Maximum area ~ 2 m^2
- Production: 1024 planes (2015-16)

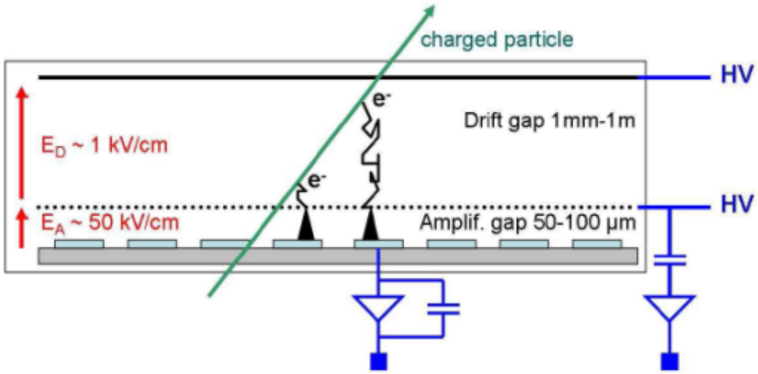
Transfer to industry:

- ELVIA (France)
- ELTOS (Italy)
- Triangle Labs (US)



GEMs vs. Micromegas





- Multiplication in the holes
- ~ 50% of electrons transferred
- Gain per layer a few 10's to 10^3
- Low ion back flow (1%)
- Multistage structure → gain 10^5
- More fragile and more integration issues

- Multiplication between mesh and anode
- Stability of gain wrt gap
- Gain 10^4-10^5
- Low ion back flow (1%, down to 10^{-6})
- Robust
- Sparking unless resistive or preceded by a GEM foil for preamplification
- Smaller ultimate thickness (both in mm and X_0)
- Slightly more radiation resistant

GEMs vs. Micromegas (2)

GEM: Sauli 1997

- COMPASS
- LHCb muon detector
- TOTEM telescope
- HBD (Hadron Blind Detector)
- NA49 (upgrade)
- X-ray polarimeter (XEUS)
- GEM TPC for LEGS, BONUS
- STAR FGT
- KLOE2 vertex detector
- OLYMPUS
- SuperBigBite (JLab/Hall A)
- CMS forward muon chambers
- ……

and at the proposal/prototyping stage

- EIC R&D
- DarkLight phase-I
- …..

MM: Giomataris 1996

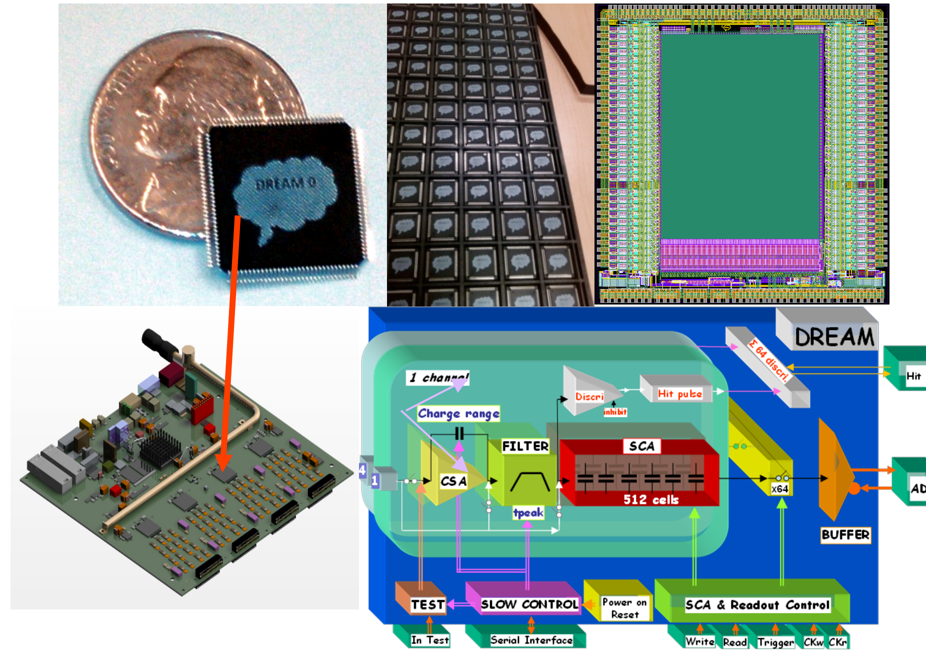
- COMPASS (1 & 2)
- NA48/KABES
- CAST (CERN Axial Solar Telescope)
- nTOF (neutron beam profile)
- Piccolo (in reactor core neutron measurement)
- T2K TPC
- JLab/CLAS12/MVT
- RIKEN/MINOS (exotic nuclei spectroscopy)
- ATLAS muon system upgrade
- …..

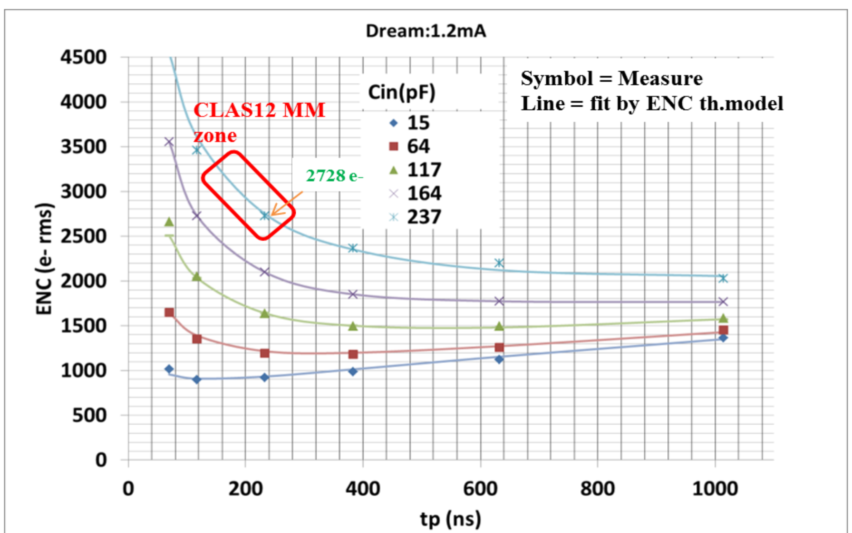
and at the proposal/prototyping stage

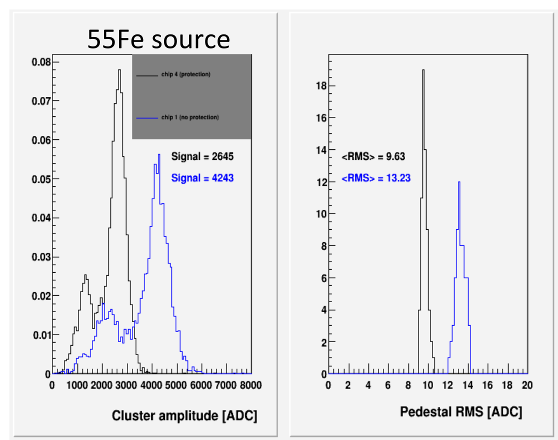
- ASACUSA (anti-H)
- HARPO (astrophysics)
- MIMAC (dark matter)
- FIDIAS & ACTAR (low-energy heavy ion)
- EIC R&D

DREAM chip

- Tailored for detectors with high capacitances
  - ~30% less noise compared to the previous generation (after ASIC)
  - Depending on detector type ENC of 2000-2700 is expected
- Version 1 submitted
  - Added intermediate peaking times for more flexibility
  - Minor bugs corrected
  - Packaged chips expected in May-June





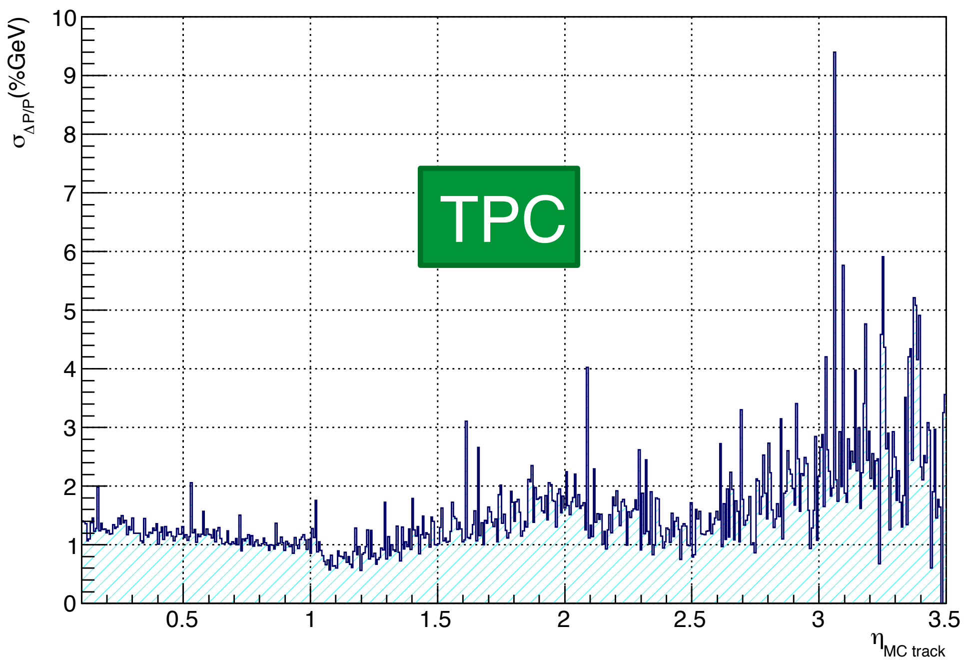


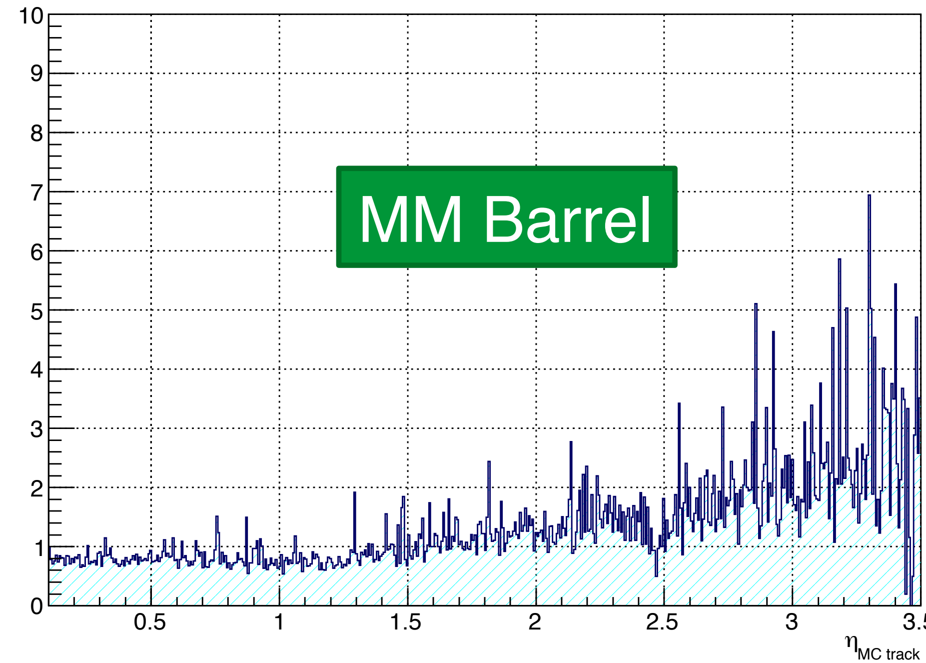
Front End Unit : Active comp. on top & bottom sides

- 8 Dream ASICs
- 8-channel 40 MHz ADC
- Virtex-6 FPGA
- SFP cages
- 2.5 Gbit/s optical link
- 1Gb Ethernet
- JTAG based system monitor

MM Barrel vs TPC

- TPC MODEL NOT USED
- Spiatial resolution simulated with smearing
  - TPC : { σ_x = 1mm, σ_y = 1mm, σ_z = 2mm }
  - MM Barel : { σ_R = 0.2mm, σ_C = 0.2mm }
- Material budget not relevant with Pions of 10 GeV/c





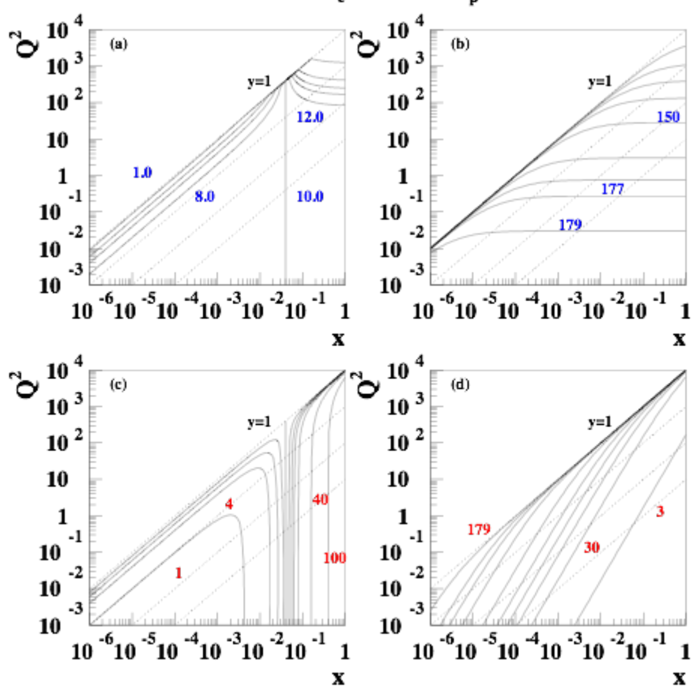
Maxence Vandenbroucke, Bernd Surrow (PI),
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

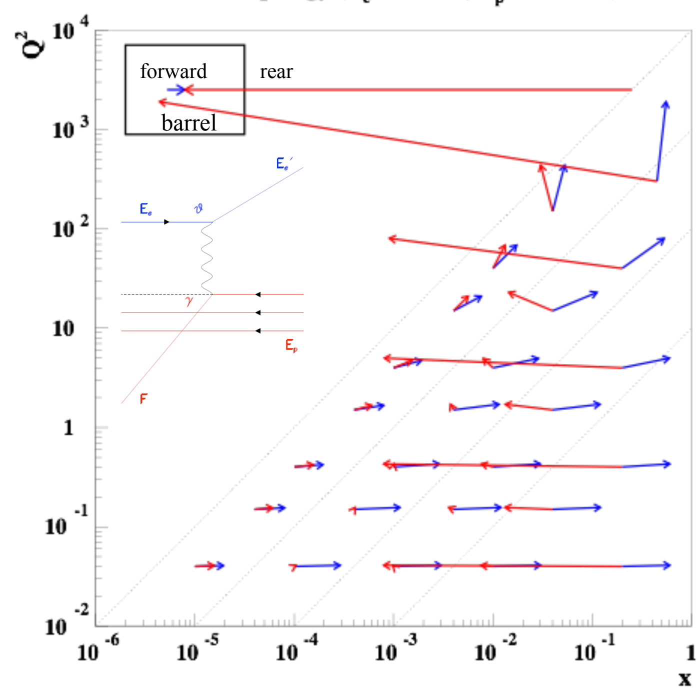
- Simulations - Overview

  - Analytical acceptance and resolution studies
  - Begun with Whitepaper 2012 layout / Started with geometry and material definition focusing on tracking system
  - Focus on micro-pattern tracking system

EIC kinematics (E_e=10 GeV, E_p=250 GeV)



EIC event topology (E_e=10 GeV, E_p=250 GeV)



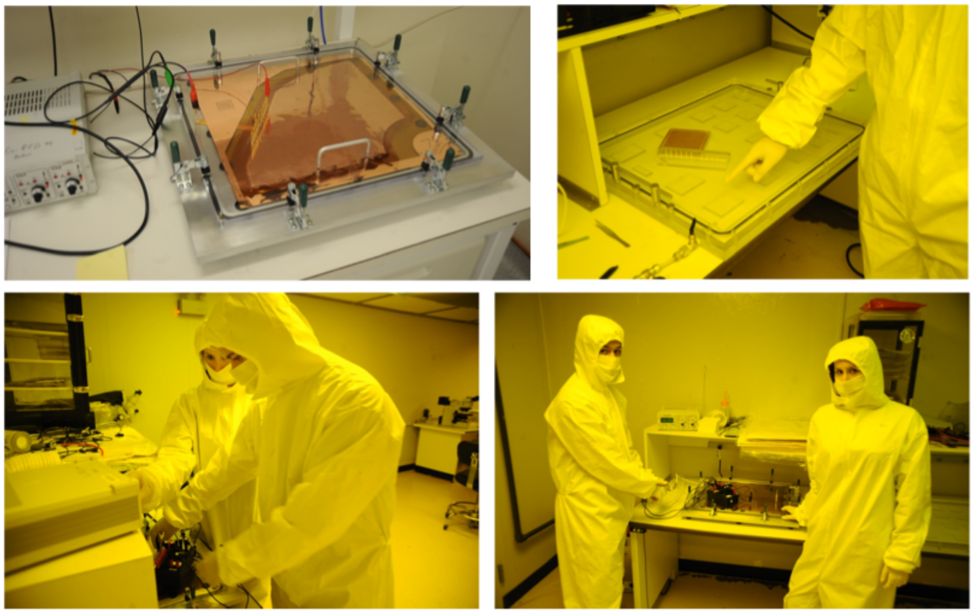
$$E_e/E_p = 0.04$$

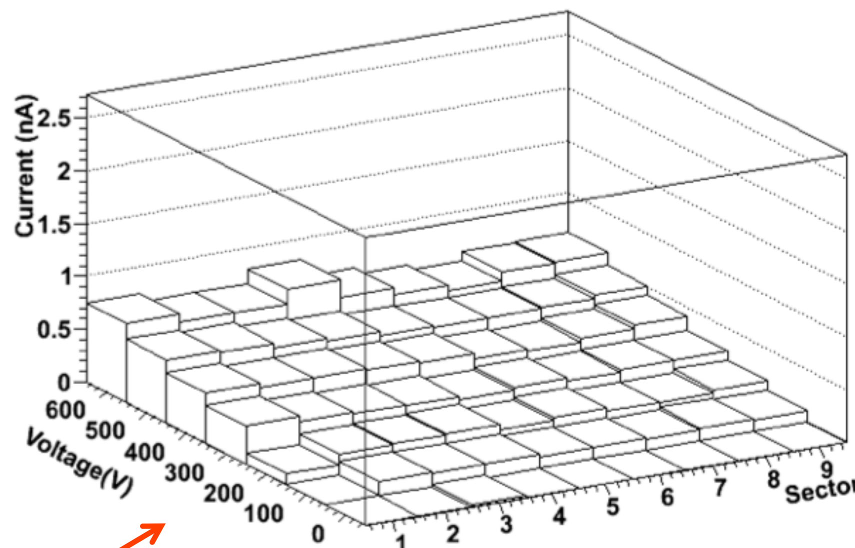
Maxence Vandenbroucke, Bernd Surrow (PI),
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

Forward GEM tracking - Leakage current

- Setup of leakage current measurement at TU / First foils tested by undergraduate students



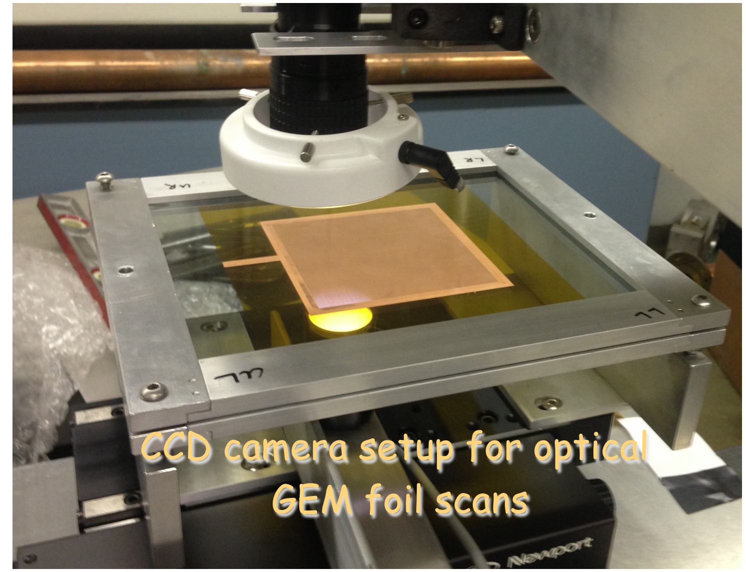


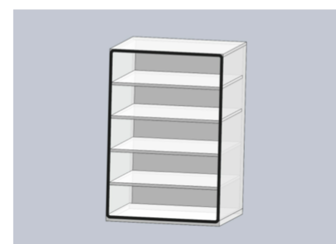
- Setup including nitrogen box with HV connections
- ISEG power supply and nA current measurement
- Example of measured leakage current performance (STAR FGT foil)

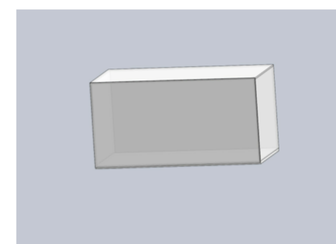
Maxence Vandenbroucke, Bernd Surrow (PI),
Doug Hasell and Franck Sabatie (PI)

Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - Optical scan
  - 2D scanning table with CCD camera fully automated
  - Scan GEM foils to measure hole diameter (inner and outer) and pitch
  - Setup routinely operated by undergraduate students
- Design of dedicated large-size N2 storage shelfs
  - SolidWork design completed. Discussion of design with TU CST mechanical engineer in January 2014
- Setup of assembly tools and design of large assembly tools
  - All assembly and stretching tools exists for FGT-type detector segments. The design and preparation of larger assembly tools will start in spring 2014 by a new mechanical engineer

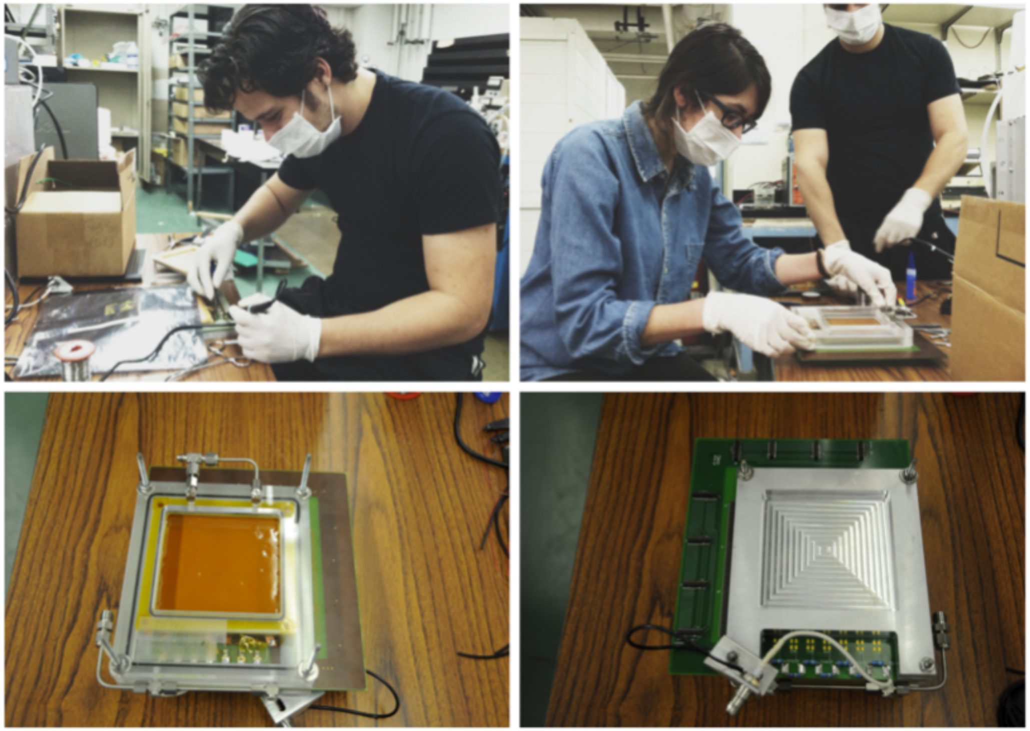


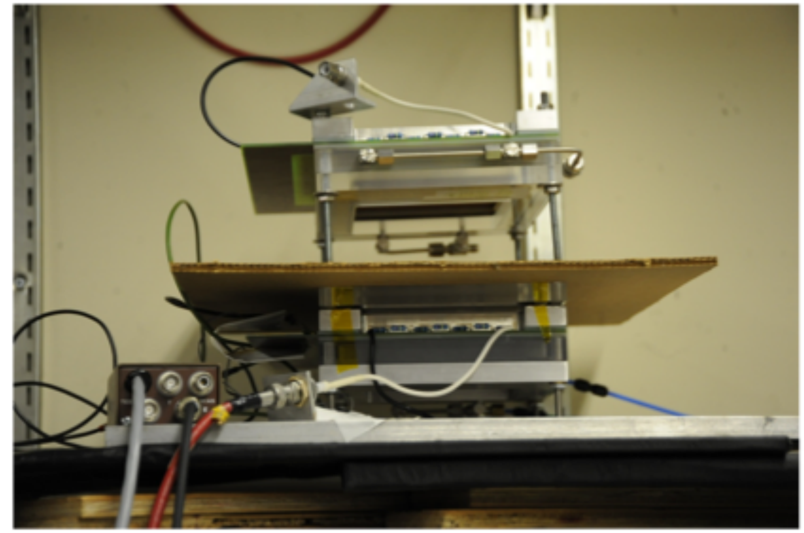

(a)

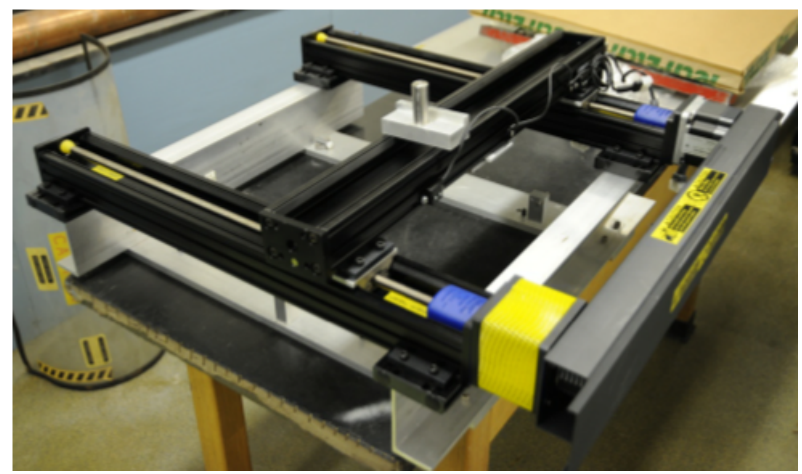

(b)

Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - Test chamber / Cosmic-ray and 55Fe source setup







- Assembly of 10x10 cm^2 prototypes by undergraduate students
- Setup of cosmic-ray test stand consisting of two plastic scintillator plates
- 55Fe scanning system in preparation

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Doug Hasell and Franck Sabatie (PI)